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GAINESVILLE, FLORIDA
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CHEMICAL STUDIES ON SOILS FROM FLORIDA CITRUS GROVES

By MICHAEL PEECH

TECHNICAL BULLETIN

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CHEMICAL STUDIES ON SOILS FROM FLORIDA CITRUS GROVES

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Although it is generally conceded among citrus growers of Florida that certain soils are more fertile than others, very little systematic information is available regarding the variation in chemical composition of the different groups of soils planted to citrus or the extent of the variation within a given group or series. A knowledge of the chemical composition of grove soils not only is of importance to proper fertilization and soil management but such information should prove invaluable to a better understanding of some of the important grove problems associated with the various soils.

The main purpose of this publication is to present chemical data on representative soil types and in a general way to evaluate the fertility of the various groups of soils planted to citrus on the basis of their chemical composition. The soils included in this study were collected in a survey made in 1937 (41)¹ of approximately 100 groves located in the various citrus areas of the state and covering a wide range of grove conditions on different soil types. Detailed notes were made by Walter Reuther of the Citrus Experiment Station staff in regard to the past fertilizer practices and the condition of the groves at the time the samples were taken.

DESCRIPTION OF SOILS

The soils planted to citrus in Florida may be divided into two major groups, (1) well drained soils, and (2) poorly drained soils. According to the classification established by the Bureau

¹Italic figures in parentheses refer to "Literature Cited" in the back of this bulletin.

of Chemistry and Soils of the U. S. Department of Agriculture, soils are grouped into series on the basis of origin, color, structure, and other characteristics. The series are further subdivided into types according to their texture or the relative amount of sand, silt, and clay in the surface layer. Thus, Norfolk sand and Norfolk fine sand are different types belonging to the Norfolk series.

WELL DRAINED SOILS

The principal soils planted to citrus within the well drained group include the following series: Norfolk, Blanton, Eustis, Lakewood, Orlando, and Gainesville. The well drained and rolling uplands are commonly referred to as "high pineland" in the ridge section and other parts of central Florida and are by far the predominant soils utilized for citrus in the state, having been planted extensively during the heaviest development of citrus, and constitute at least 70 percent of the total present acreage. Because of their excellent cold protection due to proper air drainage they are highly prized soils for this purpose, although their natural fertility is very low. In the natural state these soils support a forest growth consisting of long-leaf pine (*Pinus australis* Michx. f.), live oak (*Quercus virginiana* Mill.), turkey oak (*Q. cinerea* Michx.), and blackjack oak (*Q. laevis* Walt.), the type of growth being more or less indicative of the natural fertility of the soil. The better grades of soils in this group ("high pineland") show a preponderance of long-leaf pine (*Pinus australis* Michx. f.), turkey oak (*Q. cinerea* Michx.), and a few scattered live oaks (*Q. virginiana* Mill.), while the principal growth on poorer soils (commonly called "blackjack-oak land") consists of blackjack oak (*Q. laevis* Walt.) and scrub oaks (*Q. Chapmanii*, *Q. Rolfssii*, *Q. myrtifolia*, *Q. geminata*). Some of the best soils within the group (Norfolk fine sand, hammock phase; Eustis fine sand, dark-colored phase; Orlando fine sand; and Gainesville fine sand) locally known as "high-hammock land" support predominantly a heavy hardwood-hammock growth, which consists principally of long-leaf pine (*Pinus australis* Michx. f.), live oak (*Q. virginiana* Mill.), hickory (*Hicoria* spp.), magnolia (*Magnolia grandiflora* L.), myrtle (*Myrica* spp.), and dogwood (*Cynoxylon floridum* (L.) Raf.). The surface layer is usually thicker and darker due to the higher organic matter content, and consequently the fertility of these soils is naturally higher than that of the high pinelands.

POORLY DRAINED SOILS

The important soils in this group planted to citrus occur along the East and West coasts and in other areas over the Florida peninsula; and are commonly referred to as "low hammocks", "palmetto flatwoods", "grassy flatwoods", and "prairies", depending upon the vegetative growth, drainage conditions, and topography of the land. The "low hammocks" are characterized by a heavy growth of live oak (*Quercus virginiana* Mill.), water oak (*Q. nigra* L.), slash pine (*Pinus palustris* Mill., and *P. caribaea* Morelet in South Florida), cedar (*Sabina silicicola* Small.), hickory (*Hicoria* spp.), magnolia (*Magnolia grandiflora* L.), cabbage palmetto (*Sabal Palmetto* (Walt.) Todd.) with a heavy undergrowth of saw-palmetto (*Serenoa repens* (Bartr.) Small), myrtle (*Myrica* spp.) and other shrubs, the type of growth being dependent to some extent on the soil type and the latitude. The hammock growth on calcareous soils (Parkwood series), locally known as "marl hammocks" is confined almost entirely to cabbage palmetto (*Sabal Palmetto* (Walt.) Todd.) and live oak (*Q. virginiana* Mill.), while a mixed growth of pine and hardwood predominates on the more acid soils.

The principal flatwoods soils that are utilized for citrus include the Scranton, Bladen, Coxville, and Portsmouth series. In addition, small areas of Leon and St. Johns soils are also planted to citrus, although the presence of a well developed organic hardpan at a depth between 10 and 36 inches below the surface renders these soils unsuitable for this purpose. Because of their high organic matter content, several of the soils in this group when properly drained constitute some of the best land in the state.

Following is a brief description of important soils included in the present study. For a more complete description of these soils as well as of other soils not discussed in this publication, the reader is referred to the individual county soil survey reports and maps published by the Bureau of Chemistry and Soils, and the State Geological Survey, and to the Florida Agricultural Experiment Station Bulletin No. 334.²

Norfolk soils represent the well drained, undulating to rolling "high pineland" and "blackjack oak land". They are characterized by about 4 to 6 inches of yellowish-gray or dark-gray sand

²The Soils of Florida, by J. R. Henderson.

underlain by a yellow sand which passes into compact sandy clay beds at varying depths below the surface. These soils grade from a coarse sand (Norfolk sand) containing very little organic matter, commonly called "blackjack oak land" to a much finer sand (Norfolk fine sand), the surface layer of which is gray to dark-gray, usually having a higher content of organic matter and frequently referred to as "high pineland". Some of the better Norfolk soils (Norfolk fine sand, hammock phase) have a hammock or predominantly hardwood growth. The Norfolk soils are the most extensive soils planted to citrus in the state.

Blanton soils occupy lower areas or depressions when in association with the Norfolk soils or slight knolls within and surrounding the flatwoods. These soils differ from the Norfolk soils in that the subsoil is a pale yellow fine sand splotched with gray to grayish-yellow and underlain at varying depths, 3 to 6 feet or lower, by sandy clay beds.

Eustis soils. The surface layer of Eustis soils consists of 5 to 7 inches of a dark to grayish-brown fine sand which is underlain by a light reddish-yellow to yellowish-red fine sand. The subsoil rests on sandy clay beds several feet below the surface.

Lakewood soils have a surface layer of light gray fine sand 4 to 6 inches in thickness grading abruptly into a white incoherent fine sand 8 to 20 inches thick. This is underlain by a yellow to orange loose fine sand which at varying depths rests on reddish mottled sandy clay. Although the fertility of these soils is usually very low, they make satisfactory citrus land where the gray surface layer is at least 6 inches deep and contains an appreciable amount of organic matter and the layer of white incoherent sand is only 4 to 8 inches in thickness.

Orlando soils belong to the better group of well drained soils called "high-hammock lands". The surface layer, consisting of very dark-gray fine sand ranging from 8 to 12 inches or more in thickness and high in organic matter, is underlain by a gray loose fine sand which grades into yellow or grayish yellow fine sand at lower depths. This extends to a depth of about 5 feet overlying clay beds.

Gainesville soils, although not planted extensively to citrus, represent some of the most fertile "high-hammock land" in the citrus belt. The surface layer consists of brownish-gray loamy fine sand underlain by a reddish-brown sandy subsoil which is often quite loamy due to the presence of clay. These soils are

derived from residual material resulting from the disintegration of limestone mixed with deposits of sand and are underlain by limestone or coquina rock.

Parkwood soils are "low-hammock lands" supporting a heavy growth of cabbage palmetto (*Sabal Palmetto* (Walt.) Todd.), live oak (*Quercus virginiana* Mill.), magnolia (*Magnolia grandiflora* L.) and other hardwoods. The typical soil profile consists of a dark-gray to almost black loamy fine sand which at 2 or 3 feet passes into a whitish marly clay. Since these soils are quite variable, two different Parkwood soil profiles will be described.³ Good groves are invariably found on Parkwood soils having a profile similar to the one found in grove No. 85, samples No. 142-4, as given in Appendix Table 1. The surface layer (sample No. 142) consisted of 8 inches of dark-gray loamy fine sand, underlain by 10 inches of dingy-brown loamy fine sand (sample No. 143) which changed abruptly into a very plastic, slightly mottled yellowish clay (sample No. 144) about 6 inches in thickness resting upon marl and calcareous rock. The soil profile as found in grove No. 91, samples No. 145-6, is typical of the so-called "marl spots" which were found frequently associated with poor groves, due to a certain grove condition to be described later. The soil profile in this case consisted of 6 inches of very dark-gray to almost black sandy loam (sample No. 145) underlain immediately by a grayish to creamy-white layer of marl (sample No. 146).

Portsmouth soils are perhaps the most extensively used poorly-drained soils in the state. Many groves on acid soils in "low-hammock" areas along the East and West Coasts are located on Portsmouth soils. The surface layer is a dark-gray to gray fine sand 6 to 8 inches deep and very acid in reaction, underlain by a light-gray to almost white sandy subsoil which at varying depths several feet below the surface passes into a sticky gray, yellowish and blue-mottled sandy clay. When these soils are properly drained their fertility, like that of well drained soils, is very much dependent on the amount of organic matter in the surface layer.

Bladen soils make excellent land for citrus when properly drained. However, only a very small percentage of Bladen soils is planted to citrus. The soil profile as found in grove No. 93 consisted of 10 inches of gray to dark-gray loamy fine sand

³It is probable that several new series may be established to characterize these calcareous soils after the soil surveys are completed.

(sample No. 268) underlain by yellowish-gray plastic sandy clay (sample No. 269) which usually becomes heavier and more plastic with increasing depth and rests on bluish-gray clay mottled in places with yellow and brown.

COLLECTION AND PREPARATION OF SAMPLES

In the past fertilizer has been applied commonly over a circular area slightly larger than the actual spread of the tree; however, many growers are now spreading the fertilizer in older groves over the entire area by means of fertilizer-distributing machines. As a result, the soil is usually more acid in the area within the tree spread than in the middle of the checks. After a preliminary study, it was decided to take the soil samples just beyond the periphery of the tree or immediately outside the area of maximum leaf drip. At least 12 borings were made for each sample by means of a stainless steel tube $1\frac{1}{2}$ inches in diameter, one boring to a tree, separating all well defined soil horizons. In most of the light sandy soils in which the profile is quite simple, samples were obtained at two different depths, the gray or dark surface layer 5 to 7 inches thick being separated from the yellow, reddish-yellow, grayish-white or light-gray subsoil. The subsoil sample was taken to an arbitrary depth of 18 inches except where there was a definite change in the soil profile horizon within this depth. Both the surface soil and the subsoil borings were composited separately in the field and brought to the laboratory in quart glass jars where they were air-dried, screened through a 2 mm. aluminum sieve, and thoroughly mixed.

METHODS OF ANALYSIS

The exchangeable bases (calcium, magnesium, potassium, and manganese) were extracted by leaching a 200-gram sample of soil in a Buchner funnel with 800 ml. of 1 N ammonium acetate adjusted to pH 7.0. After washing out the excess ammonium acetate with 500 ml. of 80 percent neutral alcohol, the absorbed ammonium was replaced by leaching with 500 ml. of 10 percent solution of sodium chloride and determined by distillation in the presence of calcium hydroxide. The ammonium acetate extract containing the exchangeable bases was evaporated to dryness, and the organic matter destroyed by means of hydrogen peroxide. After dehydrating the silica, the residue was dissolved in dilute HCl, filtered, and made up to a volume of 100 ml.

Calcium.—Calcium was precipitated as the oxalate in a 40 ml. aliquot, filtered, and washed with hot water, dissolved in 10 percent H_2SO_4 and titrated with 0.05 N KMnO_4 . Prior to precipitation of calcium, iron and aluminum if present were removed with ammonium hydroxide.

Magnesium.—After the removal of calcium, magnesium was precipitated as MgNH_4PO_4 , filtered and washed with 10 percent ammonium hydroxide. After drying, the precipitate was dissolved in 0.1 N H_2SO_4 and the excess acid titrated with 0.1 N NaOH , using brom cresol green as the indicator (29).

Potassium.—An aliquot of 10 to 20 ml., depending on the amount of potassium present, of the acid solution containing the exchangeable bases was evaporated to dryness in the presence of a few drops of H_2SO_4 , and heated in an electric muffle at dull redness to expel the ammonium salts and destroy the last traces of organic matter. Potassium was then precipitated as K_2PtCl_6 , filtered and washed with 95 percent alcohol. The precipitate was dissolved in hot water, and estimated colorimetrically (13) after developing the color by the addition of an excess of KI and making up to a volume of 100 ml.

Manganese.—A 20 ml. aliquot of the original solution was evaporated to dryness in the presence of a few drops of H_2SO_4 , and ignited in an electric muffle to expel the chlorides and to destroy the organic matter. Manganese was then extracted with 20 ml. of 6 percent H_2SO_4 and determined colorimetrically (53) upon oxidation to permanganate by means of potassium periodate.

Zinc and Copper.—Zinc and copper were determined by making a separate extraction with 1 N NaCl solution. After preliminary work, sodium chloride was chosen as an extracting solution for this purpose in preference to ammonium acetate because of the greater solvent action of ammonium salts upon the insoluble salts (phosphates and carbonates) of zinc and copper. In view of the small amounts of zinc and copper present in the exchangeable form in most Florida soils it was thought that the use of 1 N NaCl solution as an extracting reagent should give a better measure of the supply of available zinc and copper.

The method finally adopted was as follows. A 100-gram sample of soil was extracted with 200 ml. of 1 N NaCl for one hour. The supernatant liquid was carefully poured off and centrifuged. A 100 ml. aliquot of the clear extract was evaporated to dryness

after the addition of 2 ml. of 30 percent hydrogen peroxide to destroy the organic matter. The residue was dissolved in 50 ml. of water containing 1.5 ml. conc. HCl. After the addition of 5 ml. of 0.7 M ammonium citrate, the solution was made slightly alkaline with ammonium hydroxide. Zinc and copper were separated by repeated extraction with .01 percent solution of dithizone dissolved in CCl_4 according to the procedure given by Sandell (44) which in turn is based on the work of Fisher (23). Zinc was then separated from copper by further extraction with .01 N HCl and determined colorimetrically by means of dithizone. The colorimetric diethyldithiocarbamate method (21) was used in the determination of copper. All reagents used in the determination of zinc and copper were carefully purified. Distilled water was redistilled in Pyrex glass.

Total Nitrogen and Nitrate Nitrogen.—Total nitrogen was determined by the Gunning-Hibbard method (2), while Harper's (30) modification was used in the determination of the nitrate nitrogen.

Organic Matter.—The organic matter content was determined by loss on ignition using the official method (2).

Acid-soluble Phosphorus.—The amount of phosphorus dissolved in .002 N H_2SO_4 , pH 3.0 according to the method proposed by Truog (51), was taken as a measure of the more readily-soluble phosphorus in the soil. Due to the heterogeneous nature of Florida light sandy soils, a larger sample of soil, 5 grams, was used instead of 2 grams as recommended by Truog to 400 ml. of the extracting solution.

Water-soluble Phosphorus.—The water-soluble phosphorus was determined in 1:5 soil-water extract.

Soil Reaction.—The pH value was measured by means of the glass electrode using equal parts of soil and water.

RESULTS OF CHEMICAL ANALYSES

The amounts of calcium, magnesium, potassium, manganese, zinc, copper, nitrate nitrogen, acid-soluble phosphorus, and water-soluble phosphorus are expressed in pounds per acre-six-inches of moisture-free soil (assuming 2,000,000 pounds per acre-six-inches of soil). In view of the vast amount of existing data on the exchangeable bases on different soil groups that have been expressed in milli-equivalents per 100 grams, the following conversion factors are given below to facilitate com-

parison of the data presented here with those published in the literature.

One	{ 401 pounds of calcium (Ca) per acre-six-inches of soil.
milli-	{ 243 pounds of magnesium (Mg) per acre-six-inches of soil.
equivalent	{ 782 pounds of potassium (K) per acre-six-inches of soil.
is	{ 549 pounds of manganese (Mn) per acre-six-inches of soil.
equivalent	{ 654 pounds of zinc (Zn) per acre-six-inches of soil.
to	{ 636 pounds of copper (Cu) per acre-six-inches of soil.

The total nitrogen and the organic matter are expressed as percentages of the oven-dry soil. Approximate location, variety, age, and general grove condition at the time of sampling are recorded also.

The various samples within the same series have been arranged in Appendix Table 1 in the increasing order of their exchange capacities in order to show the variation in the composition among the different grove soils. The minimum, maximum, and the average amounts of the various constituents found in the different soil series are presented in Appendix Table 2.

EXCHANGE CAPACITY AND THE DEGREE OF BASE SATURATION

Exchange capacity may be defined as the capacity of a soil to absorb and retain a certain group of plant nutrient elements—calcium, magnesium, potassium, manganese, ammonia, zinc, and copper—which are referred to as exchangeable bases. The total quantity of the exchangeable bases any soil can hold is a fixed quantity that can be varied only with difficulty, and is determined by the amount of organic matter or clay present in the soil. The organic matter, or more correctly, the “humus”, constitutes the main source of colloidal material in many Florida citrus soils because of the small amounts of clay present, and consequently the inorganic soil colloids contribute very little to the exchange capacity. This is substantiated by the ratios of the exchange capacity to the percent of organic matter which remain quite constant despite the great variation of the exchange capacity and the amount of organic matter in these soils. The average value of the ratio, exchange capacity/percent of organic matter, for all the soils shown in Appendix Table 1 with the exception of six samples containing appreciable amounts of clay was found to be equal to 2.0. Hence a unit increase in percentage of organic matter in the soil increases the exchange capacity approximately by 2.0 milli-equivalents per 100 grams of soil. This would give a value for the exchange capacity of the soil organic matter approximately equal to 200 milli-

equivalents per 100 grams which is in close agreement with the values of exchange capacity of the organic matter in Coastal Plain soils reported by Bartlett, Ruble and Thomas (6), as well as in other soils reported by McGeorge (36), Mitchell (37), and Olson and Bray (39). Some of the wide discrepancies noted in the ratio, exchange capacity/percent organic matter, in several samples are due to the presence of clay which would tend to make the ratios higher. It is interesting to note that five samples of marl—grove No. 84 sample No. 157, grove No. 87 samples No. 152 and 153, grove No. 91 sample No. 146, and grove No. 92 sample No. 235—have much lower exchange capacities than their textures would indicate in the field. Three of the subsoil samples of marl, Nos. 153, 146, and 235, which had an apparent texture of a heavy silt loam, showed an exchange capacity of only 3.0, 6.6, and 4.1 m.e., respectively, per 100 grams. In most of the marl samples the ratio, exchange capacity/percent organic matter, is below 2.0, which would indicate that the exchange capacities of these soils is also largely determined by their organic matter content. However, in the case of marls containing appreciable proportions of clay, the ratios are higher than 4.0.

One of the important factors affecting the exchange capacity of the soil organic matter is its stage of decomposition, the more humified portion of the organic matter having a higher exchange capacity than the fraction that has not undergone much decomposition. In considering the individual components in the soil that are responsible for base-exchange phenomena it was thought that the presence of charcoal in some of the samples was the cause of some of the variations observed in the ratios of exchange capacity to the percent of organic matter. An examination of two samples of charcoal taken from Norfolk fine sand showed an average exchange capacity of 117 milliequivalents per 100 grams of material, which is considerably lower than average for the exchange capacity of soil organic matter. Despite some of the above difficulties, the organic matter content affords a quick measure of the exchange capacity in the light sandy soils, which in turn may be regarded as the best single-value index to the relative potential fertility of the majority of the soils planted to citrus in Florida.

The exchange capacity of the surface layer of the "blackjack-oak land" and the poorer grades of "high pineland" usually varies from 1.5 to 2.0 m.e., while the better grades of "high pineland"

have an exchange capacity between 2.0 and 3.0 milli-equivalents per 100 grams. The exchange capacity of the surface layer in the "high-hammock land" is usually about 6.0, and about 10.0 or higher in the "low-hammock land".

It will be noted in Appendix Table 1 that the exchange capacity of the surface layers in sandy soils is considerably higher than that of the corresponding subsoils because of the higher organic matter content of the surface layers. This is also reflected in the greater amounts of exchangeable bases invariably present in the surface layer. The total amount of exchangeable bases such as calcium, magnesium, potassium, and manganese that a given soil may retain in a readily available form for plant use is not wholly determined by the exchange capacity but also the pH, or more correctly the percent of base saturation, must be taken into consideration. The total sum of the exchangeable bases, excluding hydrogen, expressed as percent of the exchange capacity is defined as percent base saturation. A soil is 100 percent base-saturated when the sum of the exchangeable calcium, magnesium, potassium, manganese, and other exchangeable bases (excluding hydrogen) is equal to the exchange capacity. Such a soil should have a pH value of 7.0 unless free carbonates are present, in which case the pH value is about 8.0. At 50 percent base saturation half of the exchange capacity of a soil is utilized by bases like calcium, magnesium, potassium, and the other half is saturated with hydrogen which causes soil acidity.

The relationship between the degree of base saturation of the various soil samples presented in Appendix Table 1 and their pH values is illustrated in Figure 1. Since by definition, base saturation may be interpreted as the amount of base per unit quantity of total potential soil acidity, it is evident that the relationship shown in Figure 1 is analogous to a titration curve obtained by titrating a weak monobasic acid with a strong base and the following well known buffer equation may be applied,

$$\text{pH} = \text{pK} + \log \frac{[\text{salt}]}{[\text{acid}]} \dots (1)$$

in which pK is the negative logarithm of the dissociation constant of the acid. At the point of half-neutralization, the second term of the equation becomes zero, and the pH value is numerically equal to the pK value of the acid. Bradfield (9) calculated the "apparent pK values" for several colloidal clays from the

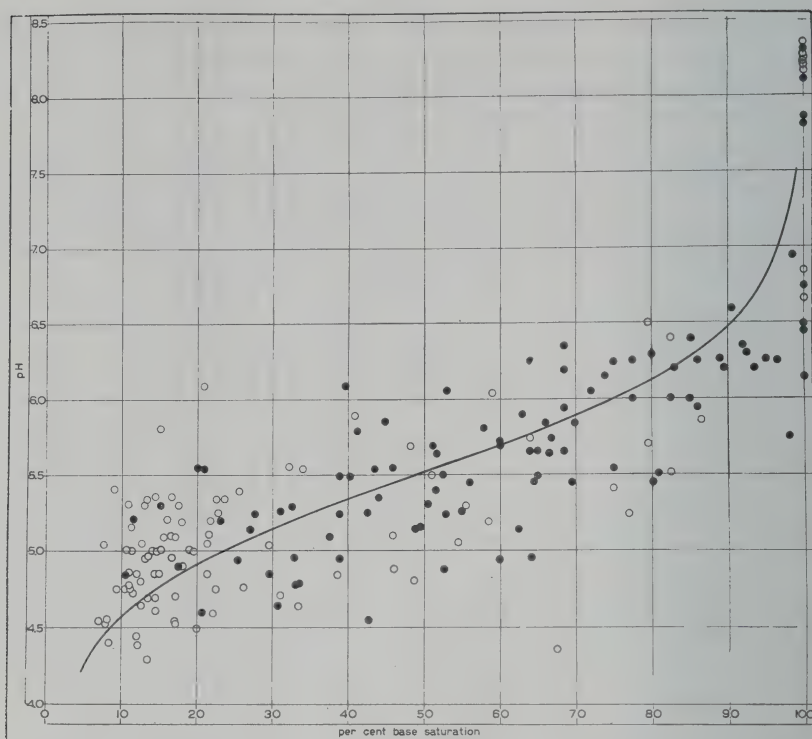


Fig. 1.—Relationship between pH value and percent of base saturation in both surface and subsoil samples. The curve represents a theoretical titration curve of monobasic acid having pK 5.52, which is the average apparent pK value found for all of the soil samples. Solid dot, surface soil; circle, subsoil.

titration curves, and showed that while such a treatment was not strictly valid, the pK values calculated from the titration curves were in close agreement with those obtained by other methods. Although not all of the exchangeable hydrogen is replaced at pH 7.0 (pH of the extracting solution used), we can apply the above relationship to base-exchange data and evaluate the average apparent pK value. Knowing the average apparent pK value it is possible to calculate the pH value, the total sum of the exchangeable bases, or the exchange capacity from any two of the three variables. Applying equation (1) to base-exchange data,

$$\text{pH} = \text{pK} + \log \frac{\text{sum of exchangeable bases excluding H}}{\text{exchangeable H}} \dots (2)$$

or

$$\text{pH} = \text{pK} + \log \frac{(\text{sum of exchangeable bases})}{(\text{exchange capacity} - \text{sum of exchangeable bases})} \dots (3)$$

At 50 percent base saturation, the observed pH is equal to the apparent pK value or the negative logarithm of the apparent dissociation constant of the absorbed hydrogen. From the data on the exchange capacity, the total sum of exchangeable bases, and the pH, the apparent pK values were calculated for the various soil samples shown in Appendix Table 1 by means of equation (3). The average apparent pK value was found to be 5.52 and was used in drawing the theoretical curve in Figure 1, showing the relationship between the pH values and the percent base saturation. There is considerable departure from the curve of some of the experimental points, probably because of the differences in nature of the base exchange complexes in the different soils and the analytical difficulties encountered in the determination of the exchangeable bases. The presence of free fertilizer salts in the soil and the solubility of the calcium, magnesium, and potassium salts of organic acids in the extracting solution as pointed out by Bray and DeTurk (10) would tend to give higher degrees of base saturation than the pH values would indicate. The majority of the surface-soil and the subsoil samples shown in Figure 1 having pH values below 5.5 showed less than 50 percent base saturation while the samples with pH values above 5.5 showed over 50 percent base saturation. It will be noted from the curve in Figure 1 that the base saturation is increased from 25 to 75 percent by raising the pH value of a soil from 5.0 to 6.0. Regardless of the exchange capacity, a given soil may be expected to contain approximately three times as much exchangeable calcium at pH 6.0 as at pH 5.0.

In view of the low exchange capacity of many Florida grove soils, it seems very desirable to maintain a high degree of base saturation by replacing hydrogen with bases like calcium and magnesium through applications of basic materials, but any attempt to raise the degree of base saturation to exceed a certain pH value might render zinc and manganese unavailable, thus inducing deficiencies of these elements (17, 19, 25). The application of basic materials to maintain the pH value of the soil at about 6.0, which corresponds approximately to 75 percent base saturation, is being tentatively recommended for best results. From the foregoing discussion it should be clear that some caution should be exercised in estimating the lime requirement of soils from pH values alone without due consideration to variation of exchange capacity in different soils. For years

many citrus growers in Florida have been very reluctant to make applications of any form of lime on grove soils, largely due to over-liming injury (25) experienced prior to 1917. In addition to this, the continuous use of acid-forming fertilizers and the resultant increase of soil acidity below pH 5.0 have aggravated the depletion of the less abundant elements in soils—magnesium, manganese, zinc, and copper—to the extent that these elements have now become the limiting factors in production in many groves on light sandy soils. Typical examples of the analyses of light sandy grove soils very acid in reaction are shown in Appendix Table 1 and are discussed later in this publication.

EXCHANGEABLE BASES

Calcium.—Since calcium is the predominating base in the colloidal complex, the amount of exchangeable calcium found in the various soils is closely correlated with the exchange capacity at approximately the same pH values. For the same reason the exchangeable calcium was found to increase with the increasing pH values in soils having the same exchange capacity. The effect of the pH value or the degree of base saturation on the actual amounts of calcium and other exchangeable bases that may be found in a surface layer of Norfolk fine sand with an average exchange capacity of 2.5 is clearly illustrated if the analysis of grove No. 28, sample No. 134, is compared with that of grove No. 29, sample No. 182. As shown in Appendix Table 2, the amount of calcium (Ca) in the surface layer of the Norfolk soils varied from 149 to 1,240 pounds per acre, the average amount being 520 pounds. The average calcium content found for the different soil series varied from 291 to 2,717 pounds per acre in the surface layer.

Magnesium.—Bahrt (3), Bahrt and Hughes (5), Bryan and DeBusk (12), and Tait (50) have reported evidence of marked responses of citrus to applications of dolomite and magnesium sulfate. The chlorotic leaf pattern due to magnesium deficiency as it occurs under field conditions in Florida has been described by Fudge (26) and Camp (16). Fudge (27) has recently made a study of the chemical composition of the fruit and the foliage and has shown that “bronzing” of citrus is definitely associated with magnesium deficiency. The majority of the light well drained upland soils which had not received an application of dolomite or soluble forms of magnesium prior to the date of sampling were found extremely deficient in magnesium, con-

taining less than 10 pounds of magnesium per acre regardless of the exchange capacity. Symptoms of magnesium deficiency were invariably found in groves located on such soils. Grove soils to which considerable amounts of bonemeal had been applied in the past contained somewhat higher quantities of exchangeable magnesium. It should be noted here that by the time this survey was undertaken, some of the grove soils sampled had received at least one application of dolomite and upon analysis showed a much higher magnesium content, although the tree response to dolomite could not be noticed at the time the samples were taken. The results of chemical analyses of the soil samples taken from groves at the Citrus Experiment Station, groves No. 12 and 16, in which the trees showed a very marked response to the application of dolomite and magnesium sulfate, are typical of the light sandy soils very acid in reaction which had never received magnesium from any of the common sources.

Many of the calcareous "low-hammock" soils were found to be well supplied with exchangeable magnesium as revealed by the analyses of the Parkwood soils. Trees growing on these soils seldom show symptoms of magnesium deficiency. On the other hand, the acid soils, such as Portsmouth, commonly associated with Parkwood soils in "low-hammock" areas contained much less and varying amounts of magnesium, depending upon the exchange capacity and the fertilizer practice. The amount of magnesium (Mg) in the surface layer of the Norfolk soils varied from 5 to 121 pounds per acre, averaging 39 pounds. The average magnesium content found for the different soil series varied from 13 to 194 pounds per acre in the surface layer.

Potassium.—Although considerable variation in the amounts of exchangeable potassium was found in soils having the same exchange capacity, there is a general increase in the amounts of exchangeable potassium with the increasing exchange capacity of the various soils. It should be noted also that the exchangeable potassium content of soils having about the same exchange capacity was usually found to increase with the increasing pH values or the degree of base saturation even where the same amounts of potash had been previously applied. The effect of the soil reaction (pH) or the degree of base saturation on the absorption of potassium from salts such as muriate or sulfate of potash can be readily explained on the basis of the position of hydrogen, calcium, and potassium in the lyotropic

series. Potassium replaces calcium more readily than it does hydrogen and consequently the efficiency of the exchange complex in absorbing potassium applied in the form of salts of strong acids is greatly increased at higher pH values because of the greater amounts of exchangeable calcium present under such conditions. Peech and Bradfield (42) have shown that the amount of potassium absorbed in exchangeable form by colloidal clay was greatly increased by increasing the degree of calcium saturation. The above considerations would further emphasize the importance of maintaining the proper soil reaction (pH) and the degree of base saturation in reducing losses by leaching not only of the common salts of potassium but other fertilizer materials generally applied in the form of salts of strong acids, such as magnesium sulfate, manganese sulfate, copper sulfate, zinc sulfate, and ammonium sulfate. If comparison is made of the small amounts of potassium found in acid sandy soils low in exchange capacity, with an average annual application of potash commonly used, it would seem that the loss of potassium through leaching in such soils has been much greater than is usually assumed. The amount of potassium (K) in the surface layer of the Norfolk soils varied from 21 to 270 pounds per acre, averaging 73 pounds. The average potassium content in the surface layer of the different soil series varied from 72 to 275 pounds per acre.

Manganese.—Skinner and Bahrt (46), Skinner, Bahrt and Hughes (47), Bahrt and Hughes (4), and Roy (43) have reported beneficial effects from applications of manganese to grove soils in Florida. The leaf symptoms of manganese deficiency were recently described by Camp and Reuther (19) and some of the conditions under which the deficiency of manganese has been aggravated in both acid and alkaline citrus soils in Florida were discussed by Camp and Peech (17) who showed that manganese deficiency in citrus is found throughout the Florida growing areas on both acid and alkaline soils. These observations of the widespread occurrence of manganese deficiency are further confirmed in this study by the fact that the majority of the soils examined were found to contain only small amounts of manganese, usually less than three pounds of exchangeable manganese per acre in the surface layer regardless of exchange capacity. From the limited number of groves examined it is impossible to say whether such small amounts of manganese are adequate to meet the requirements of citrus but it should

be pointed out that distinct leaf symptoms of manganese deficiency were observed in a large number of groves on soils containing this amount of exchangeable manganese in the surface layer.

It is interesting to note that the grove soil, sample No. 251 (grove No. 47) to which manganese sulfate had been applied, represents one of the few samples containing a larger amount (17 pounds) of exchangeable manganese. There is no relation between the exchangeable manganese content and the pH values in the case of light sandy soils, although it should be noted that two of the grove soils (groves No. 43 and 67) which had previously received large applications of lime contained less than one pound of manganese per acre. However, the manganese content of the calcareous low-hammock soils was found to be closely correlated with the pH value regardless of the previous manganese treatments. The soil samples taken from groves No. 84, 87, 91 and 92 are typical of the so-called "marl spots" usually found in the cabbage-palmetto-hammock soils where the marl layer lies close to the surface or has been mixed with the surface layer in ridging or mounding the trees. Frenching due to zinc deficiency and pronounced symptoms of manganese deficiency are usually associated with these soils, or the combination of the two symptoms sometimes locally referred to as "marl frenching".

Samples No. 142-4 and No. 145-6 were taken from two adjoining groves, Nos. 85 and 91, planted at the same time and under the same management. The surface layer (sample No. 142) of the profile in grove No. 85 consisted of 8 inches of dark loamy fine sand, underlain by 10 inches of dingy brown fine sand (sample No. 143) which changed abruptly into a very plastic, slightly mottled yellowish clay (sample No. 144) about 6 inches in thickness resting upon marl and calcareous rock. The trees in this grove were in excellent condition and some of the finest groves in the low-hammock areas were found on soils having similar profiles. The surface layer (sample No. 145) taken from the adjoining grove, No. 91, in which the trees showed symptoms of both zinc and manganese deficiencies, consisted of 6 inches of very dark to almost black sandy loam, underlain immediately by a grayish to creamy white layer of marl (sample No. 146). Although the surface layer in this type of profile as found in many other groves is strongly alkaline, about pH 8.0, the reaction of the surface layer in similar undisturbed profiles

is somewhat acid, usually about pH 6.0. The higher pH value of the surface layer in grove soils immediately underlain by marl at a depth of 8 to 10 inches is undoubtedly due to mixing of the marl layer with the surface layer in the process of ridging or mounding the trees. The reaction of the surface layer of grove soils having a profile similar to that found in grove No. 85 is seldom above pH 6.0 and in some cases may be as low as 4.8 as shown by sample No. 272, grove No. 82, in which case the marl layer was 3 feet below the surface. The marl and calcareous rock in this type of profile is usually 2 feet below the surface, underlying a heavy plastic layer of clay, the lower part of which contains some marl. It should be noted that although considerably more manganese sulfate had been applied to the soil in grove No. 91 than in the adjoining grove No. 85, the surface layer (sample No. 142) in grove No. 85 with a pH value of 5.4 showed upon analysis nine times as much exchangeable manganese as the surface layer (sample No. 145) in grove No. 91 having a pH value of 7.8. That manganese is subject to rapid oxidation and precipitation into unavailable forms in soils having pH values about 8.0 is borne out by the fact that the soil, sample No. 157, grove No. 84, which had received an application of manganese sulfate at the rate of 300 pounds per acre for three consecutive years prior to sampling showed only 0.8 pound of manganese in the exchangeable form at time of sampling. Since the manganese applications were made over a circular area around the tree, the material was actually concentrated in this area probably at the rate of 1,000 pounds per acre. It is obvious, therefore, that nothing can be gained from very heavy applications of manganese salts on marl soils at any one time in the correction of manganese deficiency, but smaller and more frequent applications should prove more efficient. In view of the cost of the large amounts of manganese that must be applied to such soils, it is more economical to resort to manganese sprays in the correction of manganese deficiency on marl soils.

Copper.—Although the use of copper in the correction of exanthema of citrus, also known in Florida as “dieback” and “ammoniation”, dates back to 1910 (24), no attempt has been made to correlate the occurrence of this physiological disorder with the available copper content of the soil. Dieback and ammoniation are often induced by excessive fertilization with

nitrogen and both soil applications of bluestone and copper sprays are used as corrective treatments.

As shown in Appendix Table 1 the amount of copper found in the different soils regardless of the exchange capacity was usually less than 0.5 pound per acre in the surface layer where no copper had been recently applied. Grove soils that had received an application of copper sulfate during the past few years prior to sampling invariably showed a higher content of exchangeable copper. The soil in grove No. 17, sample No. 158, showing 4.0 pounds of copper per acre in the surface layer had been treated with copper sulfate at the rate of 2.5 pounds per tree one year before the samples were taken. Copper sulfate was also applied to the soil in grove No. 44 at the rate of 4 pounds per tree during the year before the samples were taken and this is reflected in the higher copper content of the surface layer containing 2.6 pounds of copper per acre-six-inches. There is some evidence that copper is either fixed into non-exchangeable forms or readily lost through leaching. The trees in grove No. 62, which showed at one time severe symptoms of dieback and ammoniation, had received three applications of bluestone at the rate of 2 pounds per tree for each application during the three-year period prior to sampling but only 0.04 pound per acre of exchangeable copper was found in the surface layer when the samples were taken. A noteworthy observation in this case is that the trees did not respond to the soil application of copper, which is rather unusual since both soil applications and copper sprays are usually equally effective on acid sandy soils. According to information obtained from the grower the trees in grove No. 22 had never been treated with copper (sprays or soil applications), yet when the samples were taken the trees in this grove were in excellent condition, apparently free from the usual symptoms of copper deficiency. The amount of copper found in the surface soil was only 0.36 pound per acre which would indicate that under proper management and fertilization, especially with regard to the use of nitrogen, the amount of copper necessary for the proper growth of citrus is probably less than one pound per acre, according to the method of analysis used here. In view of the widespread use of copper as a fungicide in the control of melanose and scab, much of the copper is probably supplied in this form. Therefore, no further attempt will be made to correlate the copper content of the soils examined

in this survey with the occurrence of symptoms of copper deficiency.

Zinc.—Camp (14, 15), Camp and Reuther (18, 19), and others (20, 35, 38, 40, 49) have shown that zinc can be used effectively in the control of “frenching” or “mottle-leaf” in citrus. During the past few years many of the groves that had been severely affected with frenching have been brought back into production following a zinc spray. As shown by Camp and Reuther (19), frenching of citrus occurs in Florida most commonly on acid sandy soils (below pH 5.0) very low in exchange capacity, as well as on calcareous or over-limed soils. They concluded that zinc has been depleted in acid sandy soils as a result of leaching and fixed into unavailable form in alkaline soils. However, no studies were made of the amount of available zinc present in the various soils.

It is evident from Appendix Table 1 that the majority of the soils examined contained 3 to 5 times as much zinc as copper, although there was considerable variation in the amounts of zinc ranging from 0.16 to 1.6 pounds per acre in the surface layer in groves which had not received any soil applications of zinc materials. There was no significant difference in the exchangeable zinc content among the various soil series regardless of the exchange capacity or the organic matter content. However, the poorer grades of well drained upland soils having exchange capacities below 2.0 and which had been maintained very acid in reaction, below pH 5.0, over a period of time invariably contained less than 0.5 pound of zinc per acre in the surface layer. Typical chemical analyses of such grove soils are illustrated by samples taken from groves No. 1, 2, 3, 26, and 30, in which trees showed symptoms of zinc deficiency at the time of sampling. It has been reported previously by Floyd (25) and Camp and Reuther (19) that frenching may be readily induced by over-liming, and in view of the fact that trees growing on calcareous soils are frequently affected with frenching, it would appear that zinc is fixed and rendered unavailable in soils by lime above a certain pH value. These observations are further substantiated by the recent investigations of Lott (34) who showed that the toxicity of large applications of zinc oxide to the soils could be inhibited by liming to raise the pH values to 6.2. It is interesting to note that soils (groves No. 43, 56, and 67) which had been heavily limed at one time contained less than 0.2 pound of zinc per acre in the surface layer. Trees

in these groves showed pronounced symptoms of zinc deficiency at the time of sampling. It will also be noted that 11 out of 15 surface samples of Parkwood soils with a reaction of pH 6.0 to 8.3, with only two exceptions, showed less than 0.2 pound of zinc per acre. On the other hand, four of the remaining Parkwood soils having pH values below 6.0 in the surface layer contained a higher amount of zinc ranging from 0.3 to 2.2 pounds per acre. It has been already stated that trees are commonly affected by zinc and manganese deficiencies on these soils. Apparently zinc is fixed at pH values above 6.0, whereas the oxidation and precipitation of manganese begins above pH 7.0 and proceeds very rapidly in soils at pH 8.0.

The trees in groves No. 21, 29, and 32 were treated with zinc sulfate at the rate of 50 pounds per acre one year prior to sampling. It will be noted that the surface samples from these groves contained the highest amounts of zinc found in the survey, ranging from 2 to 5 pounds per acre. Since an application of 50 pounds of zinc sulfate (36 percent metallic zinc) is equivalent to 18 pounds of metallic zinc, the above recovery after one year is as good as might be expected on this type of soil. Jones, Gall, and Barnette (32) have reported studies on the fixation of zinc in several different Florida soils. Their results, however, showing recoveries of zinc applied as zinc sulfate to a Norfolk sand at different periods of time during the year following the application, as well as the amounts of exchangeable zinc found in the untreated soils, are much higher than those presented here. It would appear, therefore, that the ineffectiveness of soil applications of zinc sulfate as compared to the zinc spray method of treatment in the correction of frenching on light sandy soils as reported by Camp (14, 15), and Camp and Reuther (18, 19) cannot always be attributed to leaching or fixation of zinc into non-exchangeable forms. In their experiments on the correction of frenching in citrus, they found that, in the case of light sandy soils, soil applications even at the rates of 5 to 10 pounds per tree were not so effective as the zinc spray method of treatment. The failure of soil applications of zinc sulfate to correct frenching may be due, in some cases at least, to the inability of the trees to utilize zinc added to the soil because of the poor root system of the affected trees, an explanation that has been recently advanced by Chandler (20).

From the above considerations it is obvious that any recent soil applications of zinc made prior to the date of sampling

would be reflected in the analysis and would tend to obscure any relationship between the amounts of zinc found in the grove soils examined and the occurrence of frenching. In many instances it was difficult to ascertain whether zinc had been used in the spray program or included in the mixed fertilizer; hence, any further correlation of the zinc content of the soils examined with the occurrence of frenching will be dispensed with in this publication. There is a good indication, however, that frenching is caused by a deficiency of available zinc in the soil and that the range between what may be considered an adequate amount and a deficiency is probably very narrow.

ORGANIC MATTER

The organic matter content was determined by loss on ignition, a quick and an accurate method for use in light sandy soils. Since the majority of the sandy soils of Florida contain fragments of charcoal, especially at lower depths, the more tedious dry and wet combustion methods are likely to give high results, especially so if the conventional Van Bemmelen factor 1.724 is used in converting the organic carbon to organic matter. The samples that were known to contain free carbonates were treated with ammonium carbonate after the ignition in order to correct for the loss in weight due to decomposition of carbonates.

Results of determinations of the organic matter content are shown in Appendix Table 1, expressed as percent of the oven-dry soil. For purposes of comparison, 1 percent of organic matter, or any constituent, in a soil is equivalent to about 20,000 pounds per acre-six-inches of soil. It will be noted that there is considerable variation in the organic matter content among the various soil groups, or within the same soil series. The organic matter content of the Norfolk soils varied from 0.8 to 2.6 percent for the surface soils and from 0.4 to 1.4 percent for the subsoils, although the amounts of organic matter found in the subsoils were more or less constant (about 0.6 percent) in the majority of the Norfolk soils examined. Organic matter content of Eustis soils varied in the same manner. Blanton soils contained somewhat higher amounts of organic matter than the Norfolk soils. In general, the organic matter content of the poorly drained soils was higher than that of the well drained group. One surface sample of Parkwood loam, grove No. 91, contained as much as 10 percent organic matter.

The relationship between the exchange capacity and the organic matter content has been already discussed. The exchange capacity, as well as the total amount of exchangeable bases, was found directly related to the organic matter content in the majority of soils examined. The higher exchange capacity, and consequently the greater amounts of exchangeable bases of the surface soils as compared with the corresponding subsoils, can be attributed also to the differences in the relative amounts of organic matter. In addition to its base-exchange properties and moisture-holding capacity, the organic matter upon decomposition liberates nitrogen, calcium, magnesium, potassium, phosphorus, and other plant nutrient elements. The carbonic acid formed resulting from the decomposition of the organic matter increases the hydrolysis of the exchangeable bases and helps to bring into solution the more insoluble minerals and compounds in the soil.

TOTAL NITROGEN, NITRATE NITROGEN, AND THE C/N RATIO

As might be expected, total nitrogen content was found closely related to the amount of organic matter, as shown in Appendix Table 1. It has been reported by many investigators that the carbon/nitrogen ratio of the soil organic matter, or the humus, is about 10 within narrow limits depending upon climatic conditions and soil type. However, Anderson and Byers (1) reported a wide divergence among the C/N ratios of different great soil groups. They also showed considerable variation of the C/N ratio with depth. Hosking (31), working with Australian soils, found that the C/N ratio is a specific property of a soil under natural and undisturbed conditions, but that upon cultivation there is a greater loss of carbon than nitrogen, which results in a narrowing of the ratio. The C/N ratio, therefore, may be considered an important characteristic of the soil organic matter and is more or less indicative of its stage of decomposition.

In calculating the C/N ratios given in Appendix Table 1, the organic carbon was obtained by dividing the organic matter content as determined by loss on ignition by the conventional factor 1.724. While this procedure may not give the absolute values for the C/N ratios, as obtained by the direct determination of the organic carbon, because of the uncertainty of the conversion factor, the C/N ratios calculated in this manner can be used as an index to the relative decomposition of the organic matter in the various soils examined. It will be noted that

while there is a wide variation in the C/N ratios among the various samples shown in Appendix Table 1, the ratios of the surface samples remain fairly constant within a given soil series. The subsoil samples invariably showed higher and more variable ratios, probably due to fragments of charcoal which were usually found at lower depths in many of the light sandy soils examined. As shown in Appendix Table 2, the average C/N ratio of the surface samples is very nearly constant for the Norfolk, Blanton, and Eustis soils, being approximately 23. The mean value of the C/N ratio in the surface layers is 18 for Lakewood soils, 35 for both Orlando and Gainesville, 19 for Portsmouth, and 15 for Parkwood soils. Leighty and Shorey (33) have also reported a wide variation in the C/N ratio in a number of Coastal Plain soils. The 10 Norfolk profiles taken from Florida, South Carolina, and Virginia gave variable C/N ratios ranging from 7 to 26 in the surface layer. The soils reported in this study, especially those in the Orlando and Gainesville series, seem to have a higher C/N ratio than is usually found in the cultivated soils of the great soil groups. Whether the high C/N ratio of these soils may be interpreted as denoting the presence of a large quantity of decomposable organic matter or other highly carbonaceous material, such as charcoal, remains to be investigated. There is no consistent relationship between the C/N ratio of the organic matter and its exchange capacity (per unit weight) as given by the ratio, exchange capacity/percent organic matter.

It was thought desirable to make the determination of nitrate nitrogen to see if the amount of organic matter or its C/N ratio has any influence upon the formation of nitrates in the soil. As shown in Appendix Table 1, there is no apparent relationship between the amount of organic matter, the C/N ratio and the nitrate nitrogen content. Since the amount of nitrate nitrogen is subject to wide seasonal fluctuations, and is readily affected by leaching following heavy rains, as well as by fertilization, a single determination of the nitrate nitrogen in this case would hardly justify drawing any conclusions. It should be pointed out, however, that three of the Parkwood soils, groves No. 84, 87, and 91, having C/N ratios of from 12 to 14, contained from about 100 to 375 pounds of nitrate nitrogen per acre in the surface layers.

The decomposition of the plant material and the formation of ammonia and nitrate nitrogen following, for example, the plowing under of summer cover crops is also intimately asso-

ciated with the C/N ratio of the plant material incorporated with the soil. Bell (7) has made a study of the comparative rate of decomposition of several leguminous and non-leguminous cover crops in Norfolk sand with and without the addition of inorganic fertilizers in which he found a striking difference in the rate of nitrate accumulation from the various organic materials. It is generally accepted that if the C/N ratio is low as in the case of leguminous crops, ammonia and nitrate nitrogen will appear in the soil in excess of that required by the soil microorganisms for body synthesis. On the other hand, if the C/N ratio of the plant material is high the oxidation of the carbon will likely take place at the expense of the available soil nitrogen so that there may be actually a temporary depression in the amount of ammoniacal and nitrate nitrogen in the soil following the incorporation of plant material low in nitrogen. In either case the C/N ratio of the material will be narrowed and will tend to approach the C/N ratio of the soil, the value of which is more or less constant for a given set of climatic and soil conditions.

It is obvious, therefore, that the decomposition of the plant material and its subsequent effect on the accumulation of the organic matter and nitrates in the soil is influenced by the C/N ratio of the plant material. Upon decomposition only a small portion of the total plant material added goes to increase the organic matter or the humus content of the soil. In addition to the climatic factors favoring rapid decomposition of the soil organic matter in light sandy soils of Florida, the practice of intensive fertilization with complete fertilizers has, no doubt, expedited the rate of depletion of the soil organic matter. Despite the difficulties attendant in building up the amount of organic matter in well drained light sandy soils under Florida conditions, the practice of growing and turning under of summer cover crops should at least help to maintain the initial content of organic matter as shown by Stokes, Barnette, Jones, and Jefferies (48). In their studies of the effects of summer cover crops (*Crotalaria striata*, velvet beans, beggarweed, and cowpeas) on the soil organic matter as well as on the tree growth and fruit yield, they found that the organic matter content in the clean-culture plot decreased by one-third during the seven-year period of the experiment. There was also a definite correlation between the quantity of cover crops grown and the growth and fruit yield of the trees.

ACID-SOLUBLE AND WATER-SOLUBLE PHOSPHORUS

In contrast to the determination of exchangeable bases, methods that have been proposed for determination of the readily available phosphorus in soils are largely empirical, since phosphate is not exchangeable. While more recent investigations (45) have shown that phosphate is absorbed to some extent through anionic exchange by some inorganic soil colloids, it is unlikely that much of the available soil phosphorus exists in this form in the light sandy soils of Florida. It is generally considered that the reverted tri-calcium phosphate is more readily available than iron or aluminum phosphate. Consequently various acids—nitric, hydrochloric, sulfuric, acetic, citric, carbonic—of different strengths as well as alkaline salts, such as potassium carbonate, have been used to determine the nature and the availability of phosphorus in soils. Although a considerable amount of information has been gained regarding the availability of different forms of phosphorus in soils, the results obtained by such empirical methods are only relative and their use in predicting the need for phosphate fertilization must necessarily be established upon proper correlation with plant response. Among the methods proposed for the determination of the readily available phosphorus in soils, the .002 N H_2SO_4 method developed by Truog (51) has been widely used in this country. Davis and Scarseth (22) found a high degree of correlation between the amount of readily soluble phosphorus as obtained by Truog's method and the crop yields in a number of Alabama soils, including 22 representative Norfolk soils. Bryan (11) has reported that there is an accumulation of available phosphorus in old citrus groves on light sandy soils of Florida as measured by the method of Truog. The amount of water-soluble phosphorus dissolved in 1:5 aqueous extracts was also higher in the surface soil in old seedling and budded groves than in young groves.

Truog's method slightly modified was used to determine the amount of readily soluble phosphorus in the present study. Because of the heterogeneous nature of Florida light sandy soils, it is difficult to weigh out a representative 2-gram sample of soil as recommended by Truog. For this reason, a larger sample, 5 grams, was extracted with 400 ml. of the extracting solution. Upon careful checking it was found that this deviation did not affect results except in cases where the amount of phosphorus was unusually high (over 2,500 pounds P per acre).

The amount of readily soluble phosphorus as determined by this method is designated as "acid-soluble" P in Appendix Table 1. It should be noted that while this method has been used successfully in evaluating the amount of readily soluble phosphorus in acid soils it is not adapted to calcareous soils because of the poor buffer capacity of the extracting solution. This should be borne in mind in the interpretation of the data presented for Parkwood soils containing a large excess of calcium carbonate. The water-soluble phosphorus was determined in 1:5 soil-water extracts. It was necessary to flocculate some suspensions of subsoils containing appreciable amounts of clay with sodium sulfate in order to obtain clear aqueous extracts.

TABLE 1.—THE VARIATION IN THE AMOUNT OF ACID-SOLUBLE PHOSPHORUS OF THE SURFACE SAMPLES OF 93 GROVE SOILS.

Phosphorus lbs. per acre	0- 49	50- 99	100- 199	200- 299	300- 399	400- 599	600- 799	800- 999	1000- 1499	1500- 2000
Number of Groves	8	7	14	17	13	17	9	1	6	1

From Appendix Table 1 it will be noted that the acid-soluble phosphorus of the surface samples varied between wide limits ranging from 10 to 1,800 pounds per acre. As shown in Table 1 in which the groves have been arbitrarily grouped into 10 classes in accordance with the amount of phosphorus found in the surface soil, the acid-soluble phosphorus content was less than 100 pounds in 15 grove soils, between 100 and 600 pounds in 61 grove soils, and over 600 pounds in 17 grove soils. The amount of acid-soluble phosphorus was usually much higher in the surface-soil samples than in the corresponding subsoil samples, but there is a general increase in the amount of phosphorus in the subsoils with the increasing amount of phosphorus in the corresponding surface soils. It is interesting to note that in three different soils—Portsmouth, Parkwood, and Bladen (groves No. 74, 81, and 93)—collected in the vicinity of Bradenton, the amount of phosphorus was found to increase with depth. The high phosphorus content of these soils was found to be associated with a highly mottled bluish clay in the subsoil containing a large amount of acid-soluble and water-soluble phosphorus. Apparently a highly phosphatic material had been deposited with the clay and has now become more or less distributed throughout the profile. With the exception of the above soils, however, the amount of acid-soluble phosphorus was in-

variably higher in the surface layer than in the corresponding subsoil which would indicate that the readily soluble phosphorus content has been increased by fertilization. In Figure 2 the

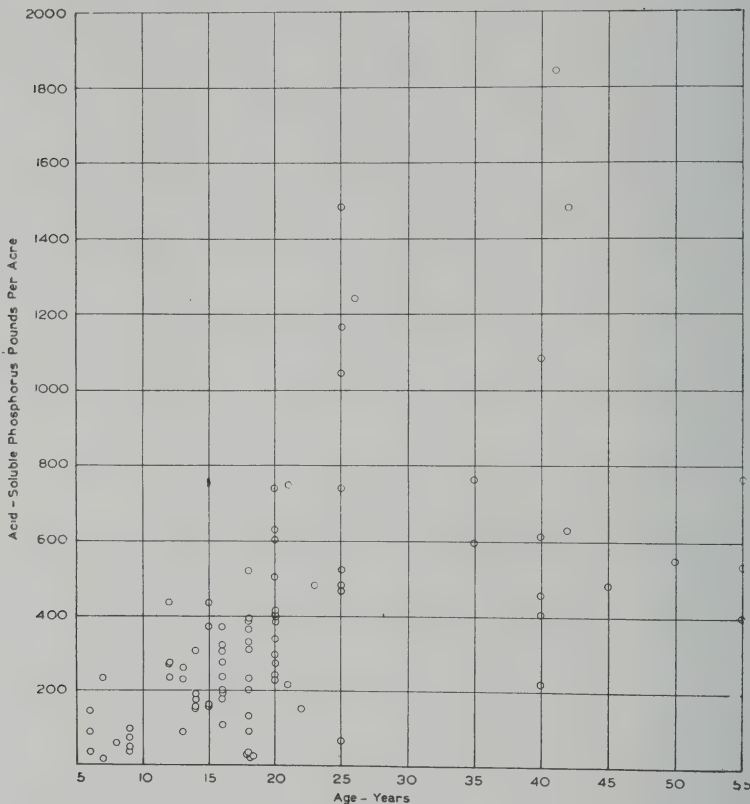


Fig. 2.—Relation of the amounts of acid-soluble phosphorus found in the surface soils to ages of the groves.

amounts of acid-soluble phosphorus in the surface samples were plotted against the ages of the respective groves. In a general way, the acid-soluble phosphorus content in the case of the surface soil samples is related to the age of the grove. However, several notable exceptions are apparent in Figure 2 which would indicate that the rate of accumulation of phosphorus in different grove soils is not constant but probably varies with soil type and other factors. That the capacity of different soils to fix phosphate varies greatly depending upon chemical composition (calcium, iron, and aluminum content) and soil reaction is well known. The exact nature of the phosphorus, soluble in .002 N H_2SO_4 according to the Truog method, that has apparently

accumulated in some of the grove soils, as well as the soil conditions under which phosphorus is "fixed" into comparatively readily soluble form, are not known at present. It has been shown by Gaarder (28), Benne, Perkins, and King (8), and others that the reversion of phosphate to tri-calcium phosphate proceeds in soils only at high pH values. Since the majority of the grove soils examined had been maintained probably below pH 5.5, it is reasonable to assume that there has been little reversion of the soluble phosphate applied as superphosphate. Hence, it is not likely that the acid-soluble phosphorus represents the reverted tri-calcium phosphate. This apparent accumulation of phosphorus in readily soluble form in some of the grove soils can hardly be attributed to fixation by iron and aluminum either, since iron and aluminum phosphates are only slightly soluble in .002 N H_2SO_4 (52). In fact, repeated tests showed only traces of soluble iron in the .002 N H_2SO_4 extracts. Some of the preliminary studies (to be published later) of factors affecting the accumulation of readily soluble phosphorus in grove soils have shown that different sources of phosphate commonly used have different residual effects as determined by Truog's method.

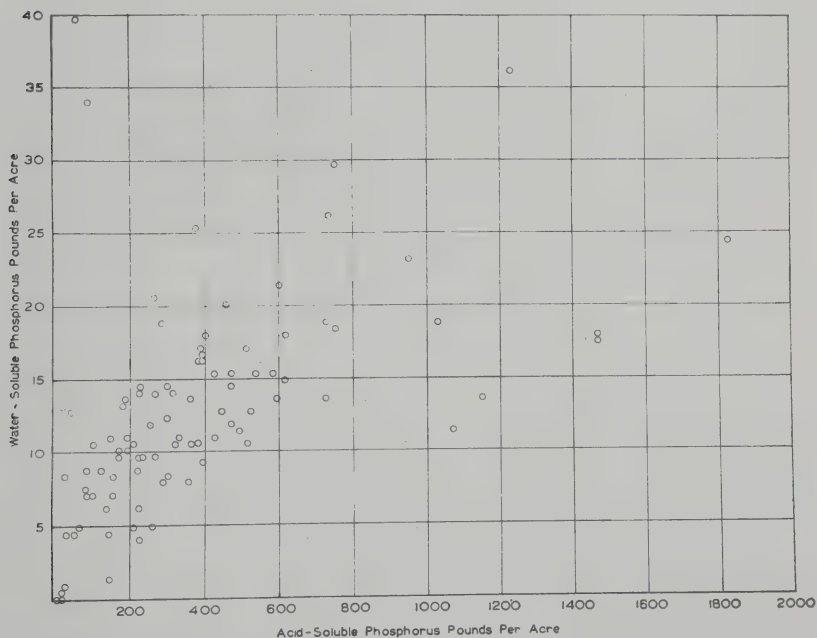


Fig. 3.—Relation of water-soluble phosphorus to acid-soluble phosphorus in the surface samples of grove soils.

The amount of water-soluble phosphorus varied from 0 to 36 pounds per acre in the surface layer. As shown in Figure 3 there is an apparent relationship between the water-soluble and the acid-soluble phosphorus in the surface samples. On the other hand, the amount of water-soluble phosphorus bears no relation to the amount of acid-soluble phosphorus in the case of subsoils. It should be noted, however, that as a rule the amount of water-soluble phosphorus in the subsoil is usually higher in groves showing a high content of acid-soluble and water-soluble phosphorus in the surface layer. It is obvious, therefore, that there is a downward movement of water-soluble phosphorus in soils showing a large amount of acid-soluble phosphorus in the surface layer. The amounts of phosphorus dissolved in 1:5 soil-water extracts are not related to the pH values of the soils, except in the case of calcareous samples which showed only traces of water-soluble phosphorus.

It is evident from the foregoing discussion that the supply of readily soluble phosphorus in the light sandy grove soils of Florida has been appreciably increased in some cases by use of phosphatic fertilizers. While the exact nature and the availability of the phosphorus as measured by the .002 N H_2SO_4 method has not been established, the large amounts of water-soluble phosphorus found in some of the groves showing high acid-soluble phosphorus content would indicate that it should be readily available. Reasons for wide differences in the amounts of acid-soluble phosphorus found among the different groves soils are obscure but probably involve a number of factors such as soil type, soil reaction, chemical composition of the soil, as well as the sources of phosphorus used. It should be mentioned here that the various experimental plots at the Citrus Experiment Station now containing widely different amounts of acid-soluble phosphorus in the soil throw little or no light as to the significance of the varying amounts of phosphorus found in the soil. Although the trees on soils containing the larger amounts of phosphorus are in better condition than those on soils having the smaller amounts of phosphorus, the present differences in the tree condition in these plots are primarily due to other factors. Until such time as the symptoms of phosphorus deficiency and phosphorus toxicity, if the latter condition actually exists, are identified and the specific effects of phosphorus on the growth of the tree, as well as on the yield and the quality of the fruit, are more thoroughly understood

it will be impossible to attach much practical significance to the wide differences in the amounts of acid-soluble phosphorus found in different grove soils.

COMPARISON OF SOME GROVE SOILS WITH THE ADJOINING VIRGIN SOILS

Only four samples of virgin soils adjoining groves No. 2, 19, 54, and 72 were included for comparison and are designated as 2V, 19V, 54V, and 72V, respectively, in Appendix Table 1. It will be noted that both the organic matter content and the exchange capacity are higher in three of the grove soils than in the corresponding virgin soils. Although the total nitrogen content has been increased, the values of the C/N ratios have decreased as a result of fertilization and cultivation. The amounts of calcium, potassium, acid-soluble phosphorus, water-soluble phosphorus, and nitrate nitrogen also have been increased by fertilization. The significance of the differences in the chemical composition observed between these grove soils and the adjoining virgin soils cannot be ascertained from the limited number of comparisons available in this study.

GENERAL DISCUSSION

It has been shown already that the base-exchange property of the majority of Florida grove soils is largely due to organic matter. Hence the problem of building up and maintaining the organic matter in light sandy soils should be of primary importance in any program of soil management. Not only is the exchange capacity the best single-value index to the fertility of the various soil types planted to citrus but it determines, within narrow limits, the total amount of exchangeable bases (calcium, magnesium, potassium) that can be maintained in the soil with a given fertilizer practice and management. This is well illustrated by the samples of Norfolk sand taken from groves No. 1, 2, 3, and 4 (Appendix Table 1) which represent the poorest grade of Norfolk soils and are typical of what is locally called "blackjack-oak land". One of the surface samples, No. 292, grove No. 2, already showing 64 percent base saturation and a pH value of 6.2, actually contains smaller amounts of exchangeable bases than the better grade of Norfolk soils having an exchange capacity about 3.0 and much lower pH values. In many instances, abrupt variations in the exchange

capacity were observed within the same soil type in the same grove. Such variations were often markedly reflected in the tree condition, especially where no adjustment had been made in the fertilizer practice. The effect of the variation of the exchange capacity upon the content of exchangeable bases is clearly depicted if we compare the analyses of the samples taken from two adjoining groves, No. 5 and 53, at approximately the same pH values. The general appearance of the trees in grove No. 5 was very poor, while those in the adjacent grove, No. 53, were in excellent condition and apparently free from any of the common deficiency symptoms, although both groves had received identical fertilizer treatment under the same management. It would be futile to attempt to maintain the same amounts of calcium, potassium, and magnesium, for example, in both of these grove soils because simple calculations show that the sum total of the exchangeable bases in the surface sample No. 200, grove No. 53, exceeds the total exchange capacity of the surface sample No. 198, grove No. 5, by 1.9 milli-equivalents per 100 grams. In order to minimize losses through leaching following heavy rainfalls in soils having such low exchange capacities (from 1.5 to 2.0 m.e.) it would seem necessary to make smaller but more frequent applications of fertilizers. The effect of the exchange capacity on the general grove condition, as shown in Appendix Table 1, has been rather accentuated in the present study by a number of limiting factors such as magnesium, manganese, zinc, and copper deficiencies, which of course were especially pronounced in groves on soils having low exchange capacities and low pH values (below 5.0). With the increasing use of these elements and the maintenance of a higher degree of base saturation by a careful control of the pH value of the soil, the differences in the grove conditions due to variations in the exchange capacity may be largely overcome.

Importance of the maintenance of organic matter content in light sandy soils is further emphasized if we compare exchange capacities and amounts of exchangeable bases in surface samples with those found in corresponding subsoil samples. During the course of sampling it was observed that most of the fine fibrous roots were present in the surface layer usually from 4 to 6 inches in depth, and that only a few fibrous roots penetrated into the yellow, gray, or grayish-white subsoil immediately below the surface layer. This limited distribution of the fibrous roots, probably due to great differences in chemical composition

between the surface layer and the subsoil, is a serious drawback during periods of drouth when the trees suffer severely from lack of moisture.

In addition to exchange capacity, variation in depth to clay beds in the case of light sandy soils has a very decided influence on the grove condition, other factors remaining constant. It was observed in several instances that in places where the clay was within 3 to 4 feet of the surface the trees appeared to be in much better condition than where the depth to clay was more than 7 feet. The beneficial effect of the clay at a depth of 3 to 4 feet is probably due to better moisture conditions and the greater efficiency of the fertilizer materials applied, since losses by leaching may be expected to be somewhat reduced under such conditions.

Problems associated with poorly drained soils along the East and West Coasts are somewhat more variable. Groves on "low-hammock" soils in which the marl layer lies either near the surface or has been mixed with the surface layer in the process of mounding or ridging the trees cause considerable trouble because of manganese and zinc deficiencies. The lack of proper drainage, and salt injury arising from salt water overflow and high salt content of irrigation waters (artesian wells) present some of the other important problems in the East and West Coast areas.

While in several instances during the course of discussion of the chemical data on the various soils, reference has been made to the general grove condition as well as to the specific deficiency symptoms, the information compiled thus far is considered inadequate for the purpose of establishing correlations and no conclusions are being drawn regarding the optimum amounts of the various nutrient elements in the soil necessary for the proper growth of citrus. Further and more specific investigations along these lines in regard to some of the elements are now being carried on.

SUMMARY

A chemical study was made of approximately 100 soils collected from groves in the important citrus areas of the state and covering a wide range of grove conditions on representative soil types. The chemical analyses included the determination of the exchange capacity; percent base saturation; exchangeable calcium, magnesium, potassium, manganese, zinc, and copper;

acid (.002 N H_2SO_4) -soluble phosphorus; water-soluble phosphorus; total nitrogen; nitrate nitrogen; organic matter (loss on ignition); and soil reaction (pH). The chemical data presented show the variations in composition among the different soil samples within the same series, as well as the minimum, the maximum, and the average amounts of the various constituents found in the different soil series. Results of analyses and some of the inferences drawn are briefly summarized below.

The well drained upland soils of the state that are most extensively planted to citrus, commonly known as "blackjack lands" and "high pinelands", including Norfolk, Blanton, Eustis, and Lakewood series, have a very low exchange capacity, usually between 2 and 3 milli-equivalents per 100 grams. The base-exchange property of these soils is largely determined by their organic matter content as shown by the constancy of the ratios, exchange capacity/percent organic matter. The exchange capacity increased approximately by 2.0 m.e. per unit increase in the percentage of organic matter. It was found that the exchange capacity affords the best single-value index to the relative potential fertility of the various soils planted to citrus. The average value for the exchange capacity of the different soil series varied from 2.7 to 8.6 milli-equivalents per 100 grams in the surface layer.

A fair general relationship was found between the degree of base saturation and the pH values in both surface and subsoil samples showing a wide variation in exchange capacity. From the data on the exchange capacity, total sum of exchangeable bases, and the pH, the average pK value of both the surface and the subsoil samples examined was calculated to be 5.5, which was found closely equal to the pH value at 50 percent base saturation. In order to provide an adequate supply of exchangeable bases in soils having such low exchange capacity, and to minimize losses by leaching of fertilizer materials applied in the form of salts of strong acids, it is highly desirable to maintain a high degree of base saturation by the addition of some form of basic material. The use of sufficient basic materials to maintain the soil reaction at about pH 6.0, which corresponds approximately to 75 percent base saturation, is being tentatively recommended for best results.

Most of the light sandy soils examined were found very deficient in magnesium, manganese, zinc, and copper. The small amounts of these elements found may be attributed to the low

levels existing in the virgin soils and to the fact that up to the present time they have been added in insufficient amounts to meet grove needs. This deficiency has been further aggravated by the excessive losses due to leaching as a result of continuous use of acid-forming fertilizers without the correction of the resultant increase of soil acidity. As a result these elements have become limiting factors in production in many groves. In many instances the amount of exchangeable magnesium found was less than 10 pounds per acre where this element had not been applied. The majority of the samples contained approximately 3 pounds of exchangeable manganese, 1 pound of zinc, and 0.5 pound of copper per acre-six-inches in the surface layer. When compared with the amounts of these elements commonly applied to the soil in correcting the deficiencies, the above amounts found seem exceedingly low.

The use of phosphatic fertilizers has, in some cases, definitely increased the amount of readily soluble phosphorus in the soil. Most grove soils were found to contain from 100 to 600 pounds of readily soluble phosphorus as determined by Truog's method. In a general way, the acid-soluble phosphorus content in surface soil samples was related to the age of the grove. The amount of water-soluble phosphorus was found to increase with the increasing amount of acid-soluble phosphorus in the surface layer. Although the exact nature and the availability of the accumulated phosphorus have not been established, the large amounts of water-soluble phosphorus found in some of the grove soils showing a high content of acid-soluble phosphorus would indicate that it should be readily available.

A wide variation in C/N ratio was found to exist among the different series with average values varying from 15 to 35, but within any given series the ratios were quite constant. Whether the high C/N ratio of these soils may be interpreted to denote the presence of a large quantity of decomposable organic matter or other highly carbonaceous material such as charcoal which was usually found, especially at lower depths, remains to be investigated.

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APPENDIX

TABLE 1.—CHEMICAL ANALYSES OF THE MAJOR CITRUS GROVE SOILS OF FLORIDA.

Soil Type ¹	Grove No.	Sample No.	Depth	pH	Base Saturation %	Exch. Capacity m.e./per 100 g. soil	Pounds per acre-six-inches of soil ²								Total N %	Organic Matter %	Ratio: Ex. Cap. % O. M.	Ratio C:N	Location	Variety	Age	General Conditions	
							Exchangeable Bases						P										Nitrate N
							Ca	Mg	K	Mn	Zn	Cu	Acid Sol.	Water Sol.									
Norfolk s.	1	290	0-5	6.06	53.0	1.39	246	21	29	0.3	0.16	0.10	88	7	5	0.023	0.91	1.53	23	Babson Park	Seedy Gft.	18	P
		291	5-18	5.30	13.0	0.74	28	2	16	0.0	0.24	0.10	22	3	0	0.010	0.53	1.40	31				
Norfolk s.	2	292	0-5	6.25	64.0	1.41	290	37	21	0.0	0.16	0.12	160	7	2	0.022	0.93	1.52	25	Frost-proof	Valencia O.	15	P
		293	5-18	4.96	13.5	0.80	28	5	13	0.0	0.16	0.06	32	2	0	0.008	0.63	1.27	46				
Norfolk s.	2V	294	0-5	5.21	11.5	1.51	56	5	11	0.4	0.32	0.06	0	1	4	0.021	1.32	1.15	36	Frost-proof	Virgin Soil	—	—
		295	5-18	5.31	10.8	0.60	13	5	10	0.1	0.16	0.06	0	0	0	0.008	0.60	1.00	44				
Norfolk s.	3	296	0-5	5.86	44.8	1.45	193	30	33	1.2	0.16	0.12	307	8	3	0.025	0.92	1.58	21	Frost-proof	Valencia O.	18?	P
		297	5-18	4.96	16.7	0.81	40	3	17	0.3	0.24	0.10	32	3	0	0.011	0.59	1.37	31				
Norfolk s.	4	300	0-6	4.96	32.8	1.54	150	19	40	1.5	1.10	0.30	227	9	2	0.028	0.99	1.56	21	Davenport	Pineapple O.	13	P
		301	6-18	4.38	12.2	0.94	28	3	25	0.0	0.32	0.30	32	1	0	0.012	0.65	1.45	31				
Norfolk f. s.	5	198	0-6	6.25	86.0	1.54	484	10	62	0.5	0.16	0.30	229	6	10	0.020	0.89	1.73	26	Apopka	Pineapple O.	18	P
		199	6-18	5.10	16.5	1.02	48	2	33	0.3	0.16	0.06	58	2	5	0.008	0.56	1.82	41				
Norfolk s.	6	306	0-6	6.25	77.5	1.64	415	43	40	1.6	0.56	0.92	227	9	2	0.028	0.98	1.68	20	Way-early	Valencia O.	20	E
		307	6-18	5.01	15.2	0.77	28	6	17	0.1	0.24	0.92	48	7	2	0.007	0.42	1.83	35				
Norfolk f. s.	7	140	0-5	5.89	51.5	1.67	300	14	41	2.3	0.96	0.14	176	9	6	0.024	0.93	1.80	22	Lake Wales	Valencia O.	14	P
		141	5-18	5.09	15.5	0.76	32	4	18	0.5	0.32	0.12	32	2	2	0.008	0.53	1.43	38				
Norfolk s.	8	298	0-6	5.25	42.5	1.70	216	29	50	1.0	4.4	0.30	480	14	4	0.028	1.06	1.60	22	Davenport	Seedy Gft.	23	P
		299	6-18	4.29	13.5	0.96	33	8	27	0.1	0.32	0.14	80	6	2	0.010	0.57	1.69	33				
Norfolk f. s.	9	124	0-6	6.30	92.5	1.71	532	50	35	2.1	0.64	0.20	272	10	11	0.032	1.25	1.37	23	Avon Park	Pineapple O.	20?	G
		125	6-18	4.35	15.0	0.80	32	6	11	0.5	0.32	0.16	32	2	0	0.009	0.63	1.27	41				

¹The following abbreviations are used in soil type: s.—sand, f.—fine, v.—very.²Based on 2 million pounds per acre-six inches of soil.³The following abbreviations are used in evaluating the general grove condition: (P)—poor, (F)—fair, (G)—good, (E)—excellent.

N.D.—not determined.

TABLE 1.—CHEMICAL ANALYSES OF THE MAJOR CITRUS GROVE SOILS OF FLORIDA—Continued.

Soil Type	Grove No.	Sample No.	Depth	pH	Base Sat. %	Exch. Cap.	Exchangeable Bases						P		Nitrate N	Total N %	Organic Matter %	Ratio: Ex. Cap. % O. M.	Ratio C:N	Location	Variety	Age	General Condition
							Ca	Mg	K	Mn	Zn	Cu	Acid Sol.	Water Sol.									
Norfolk f. s.	10	138	0-6	5.71	60.0	1.75	315	49	53	2.1	0.64	0.26	87	7	3	0.031	1.31	1.34	25	Lake Wales	Valencia O.	13	G
Norfolk f. s.	11	139	6-18	5.01	19.0	0.70	32	17	0.6	0.32	0.16	0.16	16	0	0	0.009	0.57	1.23	37				
Norfolk f. s.	11	160	0-6	5.26	31.0	1.85	194	5	55	1.0	0.56	0.24	234	14	5	0.023	1.01	1.83	35	Uma-tilla	Tangerine	16	P
Norfolk f. s.	12	161	6-18	5.01	10.6	1.11	30	5	19	0.3	0.16	0.06	55	8	0	0.009	0.56	1.98	26				
Norfolk f. s.	12	120	0-6	4.80	33.1	1.86	206	8	53	1.8	0.64	0.12	272	14	11	0.024	1.14	1.63	28	Lake Alfred	Pineapple O.	12	P
Norfolk f. s.	12	121	6-18	4.75	9.3	0.70	20	1	8	0.3	0.32	0.12	38	2	0	0.007	0.44	1.59	36				
Norfolk f. s.	13	122	0-6	6.20	93.5	1.86	600	49	32	2.7	0.48	0.50	160	8	17	0.038	1.27	1.47	19	Avon Park	Pineapple O.	5?	P
Norfolk f. s.	13	123	6-18	4.85	14.3	0.74	28	5	12	0.4	0.32	0.20	32	2	0	0.009	0.56	1.32	36				
Norfolk f. s.	14	206	0-5	5.55	45.8	1.87	316	5	37	0.9	0.48	4.2	452	13	15	0.036	1.05	1.78	17	Plymouth	Seedling O.	40+	P
Norfolk f. s.	15	207	5-18	5.19	22.7	0.92	70	3	16	0.2	0.40	3.0	80	9	18	0.010	0.45	2.04	26				
Norfolk f. s.	15	288	0-5	6.15	73.8	1.98	435	72	58	0.6	0.24	0.60	520	11	6	0.026	0.96	2.07	35	Alturas	Valencia O.	25	P
Norfolk f. s.	15	289	5-18	4.85	11.0	1.13	31	3	28	0.0	0.24	0.24	64	9	0	0.009	0.55	2.05	21				
Norfolk f. s.	16	118	0-6	4.79	33.5	2.02	230	9	49	2.2	0.64	0.20	231	14	3	0.024	1.17	1.73	28	Lake Alfred	Pineapple O.	12	P
Norfolk f. s.	16	119	6-18	4.75	10.5	0.71	20	4	8	0.5	0.32	0.12	38	3	0	0.008	0.46	1.55	33				
Norfolk f. s.	17	158	0-6	5.14	27.0	2.03	182	5	55	1.4	1.4	4.00	192	14	17	0.010	1.05	1.33	23	Uma-tilla	Pineapple O.	16	P
Norfolk f. s.	17	159	6-18	4.80	12.5	1.22	40	5	25	0.5	0.4	0.64	64	8	0	0.010	0.62	1.97	36				
Norfolk s.	18	302	0-6	4.95	38.8	2.03	238	27	57	4.7	1.8	0.88	260	12	4	0.030	1.41	1.44	27	Davenport	Valencia O.	13	G
Norfolk f. s.	18	303	6-18	4.61	14.5	0.85	36	2	20	1.0	0.32	0.22	32	3	5	0.009	0.73	1.17	47				
Norfolk f. s.	19	192	0-8	5.09	37.5	2.13	280	11	38	3.6	0.80	0.06	408	18	4	0.036	1.10	1.94	18	Lees-burg	Pineapple O.	20	E
Norfolk f. s.	19	193	8-18	4.54	17.1	1.08	55	5	20	1.7	0.40	0.04	51	8	0	0.010	0.42	2.57	24				
Norfolk f. s.	19V	194	0-6	4.84	10.5	2.02	61	8	19	2.7	0.48	0.04	13	3	0	0.019	0.93	2.17	28	Lees-burg	Virgin Soil	—	—
Norfolk f. s.	19V	195	6-18	5.41	9.0	0.89	20	3	13	0.8	0.16	0.04	22	1	0	0.007	0.41	2.17	34				
Norfolk s.	20	188	0-7	5.20	23.0	2.18	149	16	48	3.0	0.40	0.10	35	5	3	0.025	1.45	1.50	34	Lees-burg	Hamlin O.	9	P
Norfolk s.	20	189	7-18	5.36	14.4	1.01	43	5	14	0.8	0.32	0.16	16	0	0	0.010	0.74	1.49	43				
Norfolk f. s.	21	180	0-5	4.85	29.6	2.20	202	22	37	4.5	5.60	3.00	176	10	6	0.031	1.23	1.80	23	Lees-burg	Temple O.	16	G
Norfolk f. s.	21	181	5-18	4.56	8.1	1.16	22	3	18	1.7	0.48	0.50	48	3	0	0.011	0.58	2.00	31				

TABLE 1.—CHEMICAL ANALYSES OF THE MAJOR CITRUS GROVE SOILS OF FLORIDA—Continued.

Soil Type	Grove No.	Sample No.	Depth	pH	Base Sat. %	Exchangeable Bases						P		Nitrate N	Total N %	Organic Matter %	Ratio: Ex. Cap. % O. M.	Ratio C:N	Location	Variety	Age	General Condition
						Ca	Mg	K	Mn	Zn	Cu	Acid Sol.	Water Sol.									
Norfolk s. (hammock phase)	22	184	0-8	4.94	60.0	480	13	43	11.6	1.60	0.36	592	15	17	0.042	1.27	1.74	18	Min-neola	Parson Brown O.	35	G
		185	8-18	4.84	38.5	192	5	30	3.0	0.80	0.14	64	13	6	0.016	0.66	2.14	24				
Norfolk f. s.	23	126	0-6	5.99	85.0	652	69	36	3.0	0.56	0.24	294	8	22	0.045	1.41	1.64	18	Avon Park	Pineapple O.	20?	E
		127	6-18	5.11	21.5	40	8	11	0.4	0.32	0.18	32	1	10	0.008	0.57	1.20	41				
Norfolk s.	24	304	0-6	6.24	75.0	560	72	59	1.8	0.48	0.94	240	10	3	0.034	1.33	1.78	23	Way-erly	Valencia O.	20	E
		305	6-18	4.85	12.0	28	2	20	0.1	0.32	1.40	48	8	3	0.008	0.44	1.91	32				
Norfolk s.	25	308	0-6	6.59	90.5	720	67	56	1.7	0.24	0.60	400	9	5	0.036	1.45	1.64	23	Way-erly	Valencia O.	20	G
		309	6-18	5.34	22.5	43	8	23	0.1	ND	ND	48	6	2	0.007	0.59	1.27	49				
Norfolk f. s.	26	210	0-6	5.31	50.5	450	13	37	2.1	0.40	0.08	600	13	8	0.038	1.33	1.82	20	Gotha	Valencia O.	20	F
		211	6-18	5.00	14.0	60	2	18	0.4	0.24	0.06	70	7	2	0.012	0.65	1.97	31				
Norfolk f. s.	27	196	0-6	5.66	68.5	580	38	53	1.8	0.32	0.80	388	10	11	0.043	1.47	1.66	20	Apopka	Valencia O.	18	P
		197	6-18	5.05	21.3	73	2	25	0.2	0.24	0.36	64	5	1	0.010	0.50	2.06	29				
Norfolk f. s.	28	134	0-6	5.94	68.5	492	71	100	2.3	0.48	0.24	304	14	4	0.038	2.21	1.11	34	Lake Wales	Valencia O.	16	P
		135	6-18	4.95	13.1	38	10	20	0.7	0.48	0.16	80	8	0	0.011	0.60	2.07	32				
Norfolk f. s.	29	182	0-5	4.60	20.6	249	11	21	2.8	2.40	0.12	198	11	0	0.033	1.37	1.82	24	Lees-burg	Temple O.	16	F
		183	5-18	4.64	12.6	48	5	17	1.8	0.32	0.10	42	2	0	0.011	0.64	2.02	34				
Norfolk f. s.	30	218	0-6	4.94	25.3	200	11	67	2.1	0.48	0.26	154	11	11	0.039	1.41	1.77	21	Dade City	Seedy Gft.	14	P
		219	6-18	4.55	7.8	25	2	28	0.3	0.24	0.16	71	8	12	0.012	0.65	2.08	31				
Norfolk f. s.	31	136	0-6	5.50	52.5	251	32	110	4.7	0.64	0.16	368	13	5	0.039	1.61	1.56	24	Lake Wales	Valencia O.	15	E
		137	6-18	5.30	17.2	56	1	23	0.9	0.32	0.12	48	2	1	0.012	0.61	1.69	29				
Norfolk f. s.	32	176	0-5	5.24	38.8	256	56	58	4.1	3.20	0.08	106	7	9	0.039	1.73	1.48	26	Lees-burg	Hamlin O.	16	G
		177	5-18	4.74	11.5	40	8	18	1.5	0.32	0.08	32	1	4	0.013	0.95	1.45	42				
Norfolk f. s.	33	249	0-6	6.05	72.0	700	29	57	1.2	0.32	0.34	362	8	15	0.045	1.70	1.59	22	Sebring	Valencia O.	18	F
		250	6-18	5.34	13.3	36	2	22	0.1	0.24	0.24	48	4	0	0.009	0.70	1.33	45				

TABLE 1.—CHEMICAL ANALYSES OF THE MAJOR CITRUS GROVE SOILS OF FLORIDA—Continued.

Soil Type	Grove No.	Sample No.	Depth	pH	Base Sat. %	Exch. Cap.	Exchangeable Bases						P		Nitrate N	Total N %	Organic Matter %	Ratio: Ex. Cap. % O. M.	Ratio C:N	Location	Variety	Age	General Condition
							Ca	Mg	K	Mn	Zn	Cu	Acid Sol.	Water Sol.									
Norfolk f. s.	34	257	0-6	6.14	100.0	2.90	1100	76	92	3.0	0.40	0.44	1160	13	35	0.053	1.67	1.74	18	Lucerne Park	Seedy Gft.	25	P
	258	258	6-18	4.71	31.0	1.11	105	11	27	0.7	0.48	0.12	93	11	12	0.009	0.43	2.58	28				
Norfolk f. s.	35	178	0-5	5.14	48.8	2.96	500	21	78	3.2	0.40	0.30	390	16	13	0.042	1.70	1.74	23	Leesburg	Valencia O.	18	P
	179	179	5-18	4.69	13.5	1.81	76	3	29	1.5	0.32	0.36	86	13	3	0.031	0.80	2.26	15				
Norfolk f. s.	36	170	0-5	5.84	70.0	2.99	705	67	46	1.8	0.32	0.48	735	14	77	0.048	1.50	2.00	18	Umatilla	Pineapple O.	20?	P
	171	171	5-18	4.44	12.0	1.64	63	6	11	0.4	0.40	0.40	118	10	18	0.013	0.66	2.48	29				
Norfolk f. s.	37	202	0-5	6.35	92.0	3.10	1010	57	70	6.0	0.48	0.64	1080	12	9	0.053	1.68	1.85	18	Apopka	Seedling O.	40+	P
	203	203	5-18	5.69	48.2	1.32	212	13	41	2.1	0.32	0.16	122	8	3	0.014	0.70	1.88	29				
Norfolk f. s.	38	208	0-6	5.81	57.8	3.10	655	24	41	2.1	0.32	0.56	500	12	13	0.046	1.53	2.02	19	Gotha	Valencia O.	20	P
	209	209	6-18	5.19	17.9	1.47	93	3	14	0.3	0.24	0.14	80	4	2	0.014	0.76	1.94	31				
Norfolk f. s.	39	132	0-6	5.45	56.0	3.19	567	64	87	2.8	0.64	0.18	368	11	2	0.042	1.70	1.88	23	Lake Wales	Valencia O.	16	P
	133	133	6-18	4.75	11.1	1.27	36	6	19	0.8	0.56	0.12	64	5	0	0.013	0.75	1.70	33				
Norfolk f. s.	40	204	0-6	4.96	64.2	3.21	735	35	40	14.7	2.40	0.18	400	16	57	0.051	1.70	1.89	19	Plymouth	Seedling O.	40+	G
	205	205	6-18	5.04	29.5	1.20	118	6	23	1.7	0.64	0.12	93	8	5	0.010	0.59	2.03	34				
Norfolk f. s.	41	280	0-7	5.49	65.0	3.37	595	46	63	1.6	1.10	0.24	400	17	6	0.039	1.80	1.88	27	Lake Alfred	Valencia O.	20	G
	281	281	7-18	4.69	14.5	1.27	50	5	29	1.0	0.32	0.18	87	15	0	0.009	0.51	2.50	33				
Norfolk f. s.	42	172	0-5	5.35	44.0	3.40	428	63	128	4.3	1.20	0.08	432	11	11	0.040	1.88	1.81	27	Umatilla	Pineapple O.	15	G
	173	173	5-18	4.75	11.0	1.50	35	6	39	1.5	0.64	0.08	70	3	6	0.010	0.82	1.83	48				
Norfolk f. s.	43	245	0-6	6.49	100.0	3.43	1280	56	94	0.3	0.08	0.36	304	12	11	0.058	2.13	1.61	21	Cocoa	Pineapple O.	14	P
	246	246	6-18	5.89	40.8	1.15	142	15	44	0.1	0.16	0.06	58	3	0	0.010	0.60	1.92	35				
Norfolk f. s.	44	212	0-6	4.64	30.7	3.48	356	14	92	2.4	0.80	0.26	187	13	20	0.045	2.16	1.61	28	Windermere	Pineapple O.	14	P
	213	213	6-18	4.40	8.4	1.90	45	2	31	0.7	0.48	0.12	42	0	9	0.014	1.03	1.85	43				
Norfolk f. s.	45	190	0-7	5.24	27.6	3.63	305	27	98	4.3	0.40	0.08	72	5	9	0.041	2.43	1.50	34	Leesburg	Hamlin O.	9	F
	191	191	7-18	5.34	23.6	1.65	96	27	29	0.8	0.08	0.04	60	0	0	0.012	1.25	1.35	60				
Norfolk f. s.	46	255	0-6	5.75	98.0	3.68	1220	95	125	3.0	0.32	0.40	1480	18	39	0.058	1.93	1.91	19	Lucerne Park	Seedy Gft.	25	G
	256	256	6-18	4.64	33.3	1.05	100	11	40	0.6	0.24	0.12	100	11	10	0.009	0.43	2.44	28				

TABLE 1.—CHEMICAL ANALYSES OF THE MAJOR CITRUS GROVE SOILS OF FLORIDA—Continued.

Soil Type	Grove No.	Sample No.	Depth	pH	Base Sat. %	Exch. Cap.	Exchangeable Bases						P		Nitrate N	Total N %	Organic Matter %	Ratio: Ex. Cap. % O. M.	Ratio C:N	Location	Variety	Age	General Condition
							Ca	Mg	K	Mn	Zn	Cu	Acid Sol.	Water Sol.									
Norfolk f. s.	47	251	0-6	5.45	80.2	3.70	1065	27	130	17.	1.10	0.80	1840	25	24	0.062	2.03	1.82	19	Winter Haven	Valencia O.	41	G
		252	6-18	5.10	45.8	1.24	194	6	43	0.9	0.32	0.22	131	11	7	0.010	0.62	2.00	36				
Norfolk f. s.	48	130	0-7	5.69	60.0	3.78	632	121	152	0.2	1.6	0.20	320	14	3	0.043	1.91	1.98	26	Lake Wales	Valencia O.	16	P
		131	7-18	4.99	14.6	1.84	58	18	39	0.5	0.96	0.14	48	3	0	0.014	1.04	1.77	43				
Norfolk f. s.	49	247	0-6	5.51	80.8	3.80	1000	54	270	2.6	0.32	0.16	760	29	31	0.073	2.47	1.54	30	Cocoa	Valencia O.	35	G
		248	6-18	4.76	26.1	1.65	134	5	60	0.1	0.16	0.08	128	14	4	0.011	0.61	2.70	32				
Norfolk f. s.	50	278	0-7	5.66	65.0	3.99	880	65	97	1.7	1.69	0.52	1040	19	8	0.053	1.97	2.02	22	Lake Alfred	Valencia O.	25	F
		279	7-18	4.75	22.5	1.86	124	15	38	0.5	0.40	0.18	128	15	0	0.011	0.86	2.16	45				
Norfolk f. s.	51	128	0-7	5.16	49.5	4.04	568	87	175	2.0	1.6	0.20	272	21	4	0.044	2.31	1.75	30	Lake Wales	Valencia O.	16	G
		129	7-18	4.90	18.1	1.98	81	19	60	0.6	0.96	0.16	80	5	1	0.017	1.08	1.83	37				
Norfolk f. s. (hammock phase)	52	186	0-6	5.66	64.0	4.35	950	51	156	12.1	0.64	0.46	608	21	26	0.055	2.07	2.10	22	Clermont	Seedling O.	40+	P
		187	6-18	4.85	21.3	2.61	169	10	68	5.3	0.80	0.40	144	22	5	0.022	1.08	2.41	28				
Norfolk f. s. (hammock phase)	53	200	0-7	6.35	68.5	4.97	1240	24	150	1.2	0.32	0.10	326	10	5	0.047	2.24	2.21	28	Ocoee	Pineapple O.	18	E
		201	7-18	5.21	16.0	2.64	133	8	42	1.4	0.24	0.08	96	2	9	0.016	1.40	1.88	51				
Norfolk f. s.	54	220	0-6	4.90	17.5	5.00	256	29	85	2.0	0.32	0.24	150	4	18	0.064	3.10	1.61	28	Dade City	Seedy Gft.	14	G
		221	6-18	4.54	7.0	1.90	35	2	29	0.9	0.16	0.14	16	0.5	13	0.015	1.35	1.41	52				
Norfolk f. s. (hammock phase)	54V	222	0-5	5.55	20.0	4.45	252	56	23	1.1	0.32	0.14	49	3	0	0.042	2.53	1.76	35	Dade City	Virgin Soil	—	—
		223	5-18	5.81	15.1	2.73	116	27	10	0.3	0.16	0.12	42	1	0	0.020	1.56	1.65	48				
Norfolk v. f. s.	55	284	0-8	5.29	32.5	6.25	655	38	162	9.3	0.32	0.20	290	19	6	0.052	2.62	2.89	20	Homeland	Valencia O.	20	E
		285	8-18	5.05	12.7	3.04	122	6	43	1.6	0.24	0.10	80	1	0	0.016	1.45	2.10	53				
Blanton f. s.	56	310	0-9	6.19	68.5	3.51	850	18	175	1.2	0.16	0.12	200	10	8	0.040	1.99	1.77	29	Auburndale	Seedy Gft.	18	P
		311	9-18	5.04	7.6	2.12	49	3	35	0.8	0.24	0.08	40	3	2	0.014	0.91	2.33	38				
Blanton f. s.	57	168	0-7	5.90	63.0	3.74	820	43	97	7.5	2.0	0.22	625	18	15	0.039	1.45	2.58	22	Umatilla	Seedling O.	42	E
		169	7-18	5.39	25.5	1.78	144	13	31	1.5	0.32	0.00	112	17	0	0.010	0.65	2.74	38				

TABLE 1.—CHEMICAL ANALYSES OF THE MAJOR CITRUS GROVE SOILS OF FLORIDA—Continued.

Soil Type	Grove No.	Sample No.	Depth	pH	Base Sat. %	Exch. Cap.	Exchangeable Bases						P		Nitrate N	Total N %	Organic Matter %	Ratio: Ex. Cap. % O. M.	Ratio C:N	Location	Variety	Age	General Condition
							Ca	Mg	K	Mn	Zn	Cu	Acid Sol.	Water Sol.									
Blanton f. s.	58	166	0-6	5.84	66.0	3.89	875	70	66	2.5	1.1	0.68	518	17	33	0.049	1.87	2.08	22	Uma-tilla	Pineapple O.	18	P
		167	6-18	4.71	17.2	1.81	96	8	31	0.7	0.32	0.36	102	15	10	0.010	0.65	2.80	38				
		243	0-6	5.54	43.5	4.12	650	22	73	0.3	0.32	0.06	960	23	6	0.048	1.88	2.20	23	DeLand	Pineapple O.	?	E
Blanton f. s.	59	244	6-18	4.59	22.1	3.44	281	2	42	0.1	0.32	0.06	205	21	0	0.018	1.47	2.34	47				
		253	0-6	5.54	75.0	4.18	1070	78	112	3.1	0.88	0.62	735	19	39	0.057	1.85	2.26	19	Lucerne Park	Seedy Gft.	25	P
		254	6-18	4.49	20.0	1.70	101	11	34	0.7	0.56	0.30	112	14	14	0.013	0.69	2.46	31				
Blanton f. s.	61	241	0-6	5.49	40.2	4.70	605	49	135	5.0	0.32	0.14	336	11	14	0.049	2.31	2.03	27	DeLand	Hamlin O.	20	E
		242	6-18	5.16	11.3	2.66	94	3	41	1.0	0.16	0.06	80	2	0	0.020	1.62	1.64	47				
		162	0-6	5.64	51.7	2.84	485	34	94	2.5	0.32	0.04	432	15	9	0.034	1.46	1.95	25	Eustis	Valencia O.	12	P
Eustis f. s.	62	163	6-18	5.09	17.1	1.56	81	6	28	1.7	0.24	0.04	58	5	2	0.012	0.72	2.17	35				
		174	0-7	6.20	89.5	2.97	948	54	56	3.8	0.32	0.32	480	12	15	0.055	1.72	1.73	18	Tavares	See'ling O.	45	G
		175	7-18	5.50	51.0	1.98	353	19	38	4.7	0.16	0.08	146	11	2	0.018	0.96	2.06	31				
Eustis f. s.	64	164	0-6	6.39	85.2	3.32	990	51	202	8.5	0.40	0.80	1480	18	7	0.060	1.58	2.10	15	Eustis	Seedling O.	42	F
		165	6-18	5.74	64.0	1.64	363	14	61	3.9	0.16	0.06	128	19	6	0.011	0.58	2.83	31				
		286	0-7	6.29	80.0	5.27	1460	83	190	1.7	0.24	0.30	760	18	11	0.067	2.37	2.22	21	Home-land	Seedling O.	55	G
Eustis f. s.	65	287	7-18	5.56	32.1	2.82	296	13	88	1.0	0.16	0.08	120	16	3	0.041	1.12	2.51	16				
		282	0-8	5.69	51.2	6.46	1120	59	208	2.8	1.4	0.22	530	13	4	0.060	3.18	2.03	31	Bartow	Seedling O.	55	E
		283	8-18	5.00	19.5	3.60	221	7	93	1.9	0.48	0.12	120	0	0	0.023	2.12	1.70	53				
Eustis f. s. (dark-colored phase)	66	282	0-8	5.69	51.2	6.46	1120	59	208	2.8	1.4	0.22	530	13	4	0.060	3.18	2.03	31	Bartow	Seedling O.	55	E
		283	8-18	5.00	19.5	3.60	221	7	93	1.9	0.48	0.12	120	0	0	0.023	2.12	1.70	53				
Lakewood f. s.	67	238	0-6	6.00	77.5	3.24	880	54	73	1.2	0.16	0.22	397	17	20	0.057	1.67	1.94	17	Orange City	Seedling O.	55	F
		239	6-12	5.54	33.9	0.92	101	5	30	0.1	0.24	0.10	48	8	4	0.016	0.47	1.95	17				
		240	12-18	4.54	17.2	1.44	65	6	46	0.1	0.40	0.08	96	7	0	0.013	0.70	2.06	31				
Lakewood f. s.	68	263	0-7	6.74	100.0	5.65	2160	105	78	0.7	0.08	0.12	625	15	8	0.067	2.18	2.59	19	Bradenton	Valencia O.	20	F
		264	7-18	6.04	59.0	2.61	532	34	57	0.1	0.08	0.06	246	13	0	0.017	0.86	3.04	29				
Orlando f. s.	69	216	0-6	5.46	20.8	3.58	252	16	37	1.5	0.32	0.06	58	4	4	0.039	2.02	1.77	30	Orlando	Pineapple O.	8	G
		217	6-18	5.19	58.5	2.27	38	3	19	1.7	0.16	0.12	22	0	2	0.020	1.37	1.66	40				

TABLE 1.—CHEMICAL ANALYSES OF THE MAJOR CITRUS GROVE SOILS OF FLORIDA—Continued.

Soil Type	Grove No.	Sample No.	Depth	pH	Base Sat. %	Exch. Cap.	Exchangeable Bases						P		Nitrate N	Total N %	Organic Matter %	Ratio: Ex. Cap. % O. M.	Location	Variety	Age	General Condition	
							Ca	Mg	K	Mn	Zn	Cu	Acid Sol.	Water Sol.									
Orlando f. s.	70	214	0-12	5.16	15.1	6.62	329	10	106	2.5	0.32	0.12	150	2	5	0.057	4.06	1.63	41	Orlando	Pineapple O.	22	G
		215	12-24	5.00	11.3	4.52	165	6	56	1.5	0.16	0.06	23	0	6	0.039	3.12	1.45	46				
Gainesville f. s.	71	224	0-6	5.49	38.8	7.10	835	79	250	3.9	0.24	0.20	265	5	20	0.075	4.36	1.63	34	Dade City	Valencia O.	12	G
		225	6-18	5.20	21.7	3.70	242	21	84	1.3	0.08	0.06	39	0	5	0.022	2.56	1.39	70				
Gainesville f. s.	72	226	0-6	5.79	41.2	8.50	1040	125	300	2.3	0.32	0.22	231	4	14	0.086	5.50	1.55	37	Dade City	Valencia O.	7	G
		227	6-18	5.36	16.6	4.82	218	39	72	0.9	0.08	0.60	59	0	7	0.033	3.58	1.31	68				
Gainesville f. s.	72V	228	0-6	6.09	39.6	6.65	795	141	52	0.7	0.08	0.08	49	3	0	0.066	4.60	1.45	40	Dade City	Virgin Soil	—	I
		229	6-18	6.09	20.8	4.10	238	55	26	0.3	0.08	0.06	39	1	0	0.030	3.10	1.32	60				
Portsmouth f. s. (hardpan phase)	73	274	0-8	4.55	42.7	2.95	440	21	58	3.3	1.4	0.16	64	39	0	0.047	1.52	1.94	19	Palmetto	Seedy Gft.	25	P
		275	8-18	4.36	67.5	0.80	172	13	44	0.8	0.96	0.08	16	11	0	0.012	0.55	1.45	27				
Portsmouth f. s.	74	276	0-8	5.94	86.0	3.70	1140	45	102	1.8	0.16	0.24	465	20	4	0.061	1.58	2.34	15	Bradenton	Seedy Gft.	25	E
		277	8-18	5.51	82.5	11.0	2650	495	332	1.7	0.16	0.06	2280	47	0	0.033	1.41	7.80	25				
Portsmouth f. s.	75	150	0-11	5.64	66.5	3.73	775	102	80	1.7	0.32	0.12	32	8	7	0.046	1.87	2.00	24	Vero Beach	Valencia O.	18	P
		151	11-24	5.30	55.5	0.87	148	21	22	0.7	0.48	0.10	10	4	2	0.011	0.53	1.65	28				
Portsmouth f. s.	76	154	0-12	5.26	55.0	5.48	910	133	140	5.1	0.24	0.12	26	13	6	0.054	2.14	2.56	23	Vero Beach	Marsh Gft.	18	G
		155	12-18	5.06	54.5	0.86	152	16	19	0.5	0.48	0.12	10	3	2	0.011	0.56	1.54	30				
Portsmouth f. s.	77	156	0-18	5.14	62.5	9.35	1860	236	171	1.1	0.40	0.14	33	1	20	0.124	3.29	2.84	15	Vero Beach	Marsh Gft.	6	E
Parkwood f. s.	78	270	0-10	5.24	52.8	3.62	635	59	72	2.6	1.60	1.2	48	13	0	0.059	1.86	1.95	18	Bradenton	Seedy Gft.	9	P
		271	10-24	5.24	77.0	1.18	304	24	37	2.5	0.72	0.14	32	10	0	0.019	0.58	2.04	20				
Parkwood f. s.	79	261	0-7	5.74	66.8	3.70	890	16	138	2.6	2.20	0.32	384	25	9	0.060	1.51	2.45	15	Bradenton	Seedy Gft.	20	G
		262	7-14	4.81	48.7	2.42	334	29	76	5.2	0.56	0.10	55	17	0	0.016	0.50	4.85	18				
Parkwood f. s.	80	259	0-7	6.26	89.0	4.58	1430	73	136	6.1	0.64	0.22	476	15	8	0.073	1.81	2.53	14	Bradenton	Seedy Gft.	25	P
		260	7-14	5.70	79.5	3.00	772	86	64	11.5	0.32	0.10	80	13	1	0.017	0.55	5.45	19				
Parkwood f. s.	81	265	0-7	6.25	96.5	4.75	1680	75	69	2.7	0.08	0.12	545	15	7	0.070	1.90	2.50	16	Bradenton	Seedy Gft.	50	G
		266	7-14	5.41	75.0	3.82	895	130	74	6.1	0.32	0.06	592	24	0	0.018	0.67	5.70	22				
Parkwood f. s.	267	14-24	6.84	100.0	13.2	3680	1030	247	1.7	0.16	0.06	3200	33	0	0.030	1.81	7.30	35					

TABLE 1.—CHEMICAL ANALYSES OF THE MAJOR CITRUS GROVE SOILS OF FLORIDA—Concluded.

Soil Type	Grove No.	Sample No.	Depth	pH	Base Sat. %	Exch. Cap.	Exchangeable Bases						P		Nitrate N	Total N %	Organic Matter %	Ratio: Ex. Cap. % O. M.	Ratio C:N	Location	Variety	Age	General Condition
							Ca	Mg	K	Mn	Zn	Cu	Acid Sol.	Water Sol.									
Parkwood f. s.	82	272	0-10	4.88	52.7	5.46	985	57	148	1.5	0.48	0.08	96	34	6	0.070	2.32	2.35	19	Bradenton	Seedy Gft.	9	E
		273	10-24	4.88	46.0	4.05	528	86	150	0.8	0.96	0.12	192	17	0	0.029	1.23	3.30	25				
Parkwood f. s. loam	83	148	0-7	6.20	83.0	5.75	1320	266	307	2.8	0.24	0.12	144	6	22	0.073	2.44	2.36	19	Vero Beach	Marsh Gft.	6	G
		149	7-13	6.40	82.5	3.20	625	194	228	1.5	0.24	0.12	19	1	7	0.034	1.35	2.37	23				
Parkwood clay loam	84	157	0-8	8.31	100.0	6.60	2070	284	210	0.4	0.16	0.36	13	0	97	0.125	3.05	2.16	14	Vero Beach	Marsh Gft.	7	G
Parkwood s. loam	85	142	0-8	5.46	64.5	6.95	1300	227	196	9.3	0.32	0.14	129	9	18	0.016	2.79	2.49	10	Vero Beach	Seedy Gft.	18	G
		143		6.50	79.5	5.72	1210	347	93	0.8	0.32	0.10	20	0	6	0.038	2.22	2.58	34				
		144		8.16	100.	14.0	3950	950	200	0.6	0.16	0.12	10	0	2	0.076	5.25	2.69	40				
		147		6.26	95.0	7.68	2240	310	301	3.9	0.16	0.12	88	9	24	0.095	2.54	3.02	16	Vero Beach	Valencia O.	6	P
Parkwood clay loam	87	152	0-12	8.11	100.0	7.85	2300	465	175	1.3	0.16	0.26	26	0	101	0.209	4.33	1.82	12	Vero Beach	Seedy Gft.	18	P
		153	12-18	8.20	100.0	8.06	725	272	113	0.4	0.16	0.18	10	0	8	0.098	2.52	1.22	15				
Parkwood f. s. loam	88	232	0-8	6.00	82.5	9.00	2660	132	154	6.6	0.16	0.10	108	11	5	0.109	3.42	2.63	18	Wild-wood	Pineapple O.	?	G
		233	8-18	8.29	100.	17.7	6250	445	209	0.3	0.08	0.12	13	0	4	0.072	4.30	4.12	35				
Parkwood loamy f. s.	89	236	0-6	6.44	100.	11.6	4350	117	198	1.8	0.16	0.30	745	26	7	0.172	3.80	3.05	13	Titusville	Pineapple O.	21	G
		237	6-14	6.66	100.	4.72	1760	52	67	0.6	0.08	0.12	169	13	11	0.048	1.20	3.95	14				
Parkwood f. s. loam	90	230	0-8	6.94	98.5	14.7	5450	183	261	5.3	0.16	0.10	216	11	5	0.130	3.70	4.00	16	Wild-wood	Parson Brown O.	40	G
		231	8-16	8.19	100.	27.6	9700	750	122	0.3	0.08	0.08	10	0	4	0.076	5.42	5.08	41				
Parkwood loam	91	145	0-6	7.86	100.	17.9	6450	347	313	0.8	0.16	0.24	25	1	375	0.517	10.6	1.70	12	Vero Beach	Seedy Gft.	18	P
		146	6-18	8.19	100.	6.63	2200	215	195	0.3	0.16	0.18	10	0	154	0.219	4.95	1.34	13				
Parkwood f. s. loam	92	234	0-6	7.81	100.	19.3	7000	308	416	0.8	0.08	0.80	214	5	33	0.389	8.90	2.17	13	Titusville	Pineapple O.	21	P
		235	6-18	8.35	100.	4.10	1315	139	178	0.6	0.08	0.20	22	0	13	0.086	2.35	1.75	16				
Bladen f. s. loam	93	268	0-10	5.45	69.5	5.31	1215	73	266	26.6	0.56	0.14	1240	36	6	0.065	1.68	3.16	15	Bradenton	Valencia O.	26	F
		269	10-24	5.86	86.5	21.6	5700	795	855	12.0	0.16	0.06	3160	96	0	0.040	2.25	9.60	33				

TABLE 2.—MINIMUM, MAXIMUM, AND AVERAGE AMOUNTS OF VARIOUS CONSTITUENTS FOUND IN DIFFERENT CITRUS GROVE SOILS.

Soil Series	No. of Sam- ples	Depth	pH	Base Sat- uration %	Exch. Cap. m.e./ 100 g.	Pounds per acre-six-inches of soil										Total N %	Organic Matter %	Ratio: Ex.Cap. % O.M. C:N							
						Exchangeable Bases					P		Ni- trate N	Acid Sol.	Cu				Zn	Mn	K	Mg	Ca		
						Min.	Max.	Aver.	Min.	Max.	Aver.	Min.												Max.	Aver.
Norfolk	55	Surface Soil	Min.	4.60	17.5	1.39	149	5	21	0.2	0.08	0.06	35	4	0	0.020	0.89	1.11	17						
			Max.	6.59	100.	6.25	1240	121	270	17.	5.6	4.2	1840	29	77	0.073	3.10	2.39	34						
	55	Subsoil	Aver.	5.56*	57.3	2.72	520	39	73	3.2	0.91	0.55	408	12	13	0.039	1.56	1.73	23						
			Min.	4.29	7.0	0.68	20	1	8	0.0	0.08	0.04	6	0	0	0.007	0.42	1.17	15						
Blanton	6	Surface Soil	Max.	5.89	48.2	3.04	212	27	68	5.3	0.96	3.0	144	22	18	0.031	1.45	2.70	60						
			Aver.	5.03	17.8	1.26	66	6	26	0.8	0.36	0.26	61	6	3	0.011	0.70	1.84	36						
	6	Subsoil	Min.	5.49	40.2	3.51	605	18	66	0.3	0.16	0.06	200	10	6	0.039	1.45	2.03	19						
			Max.	6.19	75.0	4.70	1070	78	175	7.5	2.0	0.68	960	23	39	0.067	2.31	2.58	29						
Eustis	5	Surface Soil	Aver.	5.75	59.4	4.02	812	47	110	3.3	0.80	0.31	566	16	19	0.047	1.90	2.23	24						
			Min.	4.49	7.6	1.70	40	2	31	0.1	0.16	0.04	40	2	0	0.010	0.65	1.64	31						
	5	Subsoil	Max.	5.39	22.1	3.44	281	13	42	1.5	0.56	0.36	205	21	14	0.020	1.62	2.80	47						
			Aver.	4.90	17.3	2.25	126	7	36	0.8	0.32	0.15	109	12	4	0.014	1.00	2.40	40						
Lakewood	5	Surface Soil	Min.	5.64	51.2	2.84	485	34	56	1.7	0.24	0.04	432	12	4	0.034	1.46	1.73	15						
			Max.	6.39	89.5	6.46	1460	83	208	8.5	1.4	0.80	1480	18	15	0.067	3.18	2.22	31						
	5	Subsoil	Aver.	6.04	71.5	4.17	1001	56	150	3.9	0.54	0.34	740	15	9	0.055	2.06	2.00	22						
			Min.	5.00	17.1	1.56	81	6	28	1.0	0.16	0.04	58	0	2	0.011	0.58	1.70	16						
Lakewood	2	Surface Soil	Max.	5.74	64.0	3.60	363	19	88	4.7	0.48	0.12	146	19	6	0.041	2.12	2.83	53						
			Aver.	5.38	36.7	2.32	263	12	62	2.6	0.24	0.08	115	11	3	0.021	1.10	2.25	33						
	3	Subsoil	Min.	6.00	77.5	3.24	880	54	73	0.7	0.08	0.12	397	15	8	0.057	1.67	1.94	17						
			Max.	6.74	100.	5.65	2160	105	78	1.2	0.16	0.22	625	17	20	0.067	2.18	2.59	19						
Lakewood	3	Subsoil	Aver.	6.37	88.7	4.45	1520	79	76	0.9	0.12	0.17	514	16	14	0.062	1.93	2.27	18						
			Min.	4.54	5.9	0.92	65	5	39	0.1	0.08	0.06	48	7	0	0.013	0.47	1.95	17						
	3	Subsoil	Max.	6.04	33.9	2.61	532	34	57	0.1	0.40	0.10	248	13	4	0.017	0.86	3.04	31						
			Aver.	5.37	19.0	1.66	233	15	44	0.1	0.24	0.08	131	9	1	0.015	0.68	2.35	26						

*Arithmetical average of pH values rather than of the actual hydrogen ion concentration.

TABLE 2.—MINIMUM, MAXIMUM, AND AVERAGE AMOUNTS OF VARIOUS CONSTITUENTS FOUND IN DIFFERENT CITRUS GROVE SOILS.—Concluded.

Soil Series	No. of Samples	Depth	pH	Base Sat. %	Exch. Cap.	Exchangeable Bases						P		Total N %	Organic Matter %	Ratio: Ex.Cap. % O.M.	Ratio C:N		
						Ca	Mg	K	Mn	Zn	Cu	Acid Sol.	Water Sol.						
Orlando	2	Surface Soil	Min.	5.16	15.1	3.58	252	10	37	1.5	0.32	0.06	58	2	4	0.039	2.02	1.63	30
			Max.	5.46	20.8	6.62	329	16	106	2.5	0.32	0.12	150	4	5	0.057	4.06	1.77	41
	2	Subsoil	Aver.	5.30	18.0	5.10	291	13	72	2.0	0.32	0.09	104	3	4	0.048	3.04	1.70	35
			Min.	5.00	11.3	2.27	38	3	19	1.5	0.16	0.06	22	0	2	0.020	1.37	1.45	40
Gainesville	2	Surface Soil	Max.	5.19	58.5	4.52	165	6	56	1.7	0.16	0.12	23	0	6	0.039	3.12	1.66	46
			Aver.	5.10	34.9	3.40	102	5	37	1.6	0.16	0.09	23	0.2	4	0.030	2.25	1.56	43
	2	Subsoil	Min.	5.49	38.8	7.10	835	79	250	2.3	0.24	0.20	231	4	14	0.075	4.36	1.55	34
			Max.	5.79	41.2	8.50	1040	125	300	3.9	0.32	0.22	265	5	20	0.086	5.50	1.63	37
Portsmouth	5	Surface Soil	Aver.	5.64	40.0	7.80	938	102	275	3.1	0.25	0.21	250	4	17	0.081	4.93	1.59	35
			Min.	5.20	16.6	3.70	218	21	72	0.9	0.08	0.06	39	0	5	0.022	2.66	1.31	68
	4	Subsoil	Max.	5.36	21.7	4.82	242	39	84	1.3	0.08	0.60	59	1	7	0.033	3.68	1.39	70
			Aver.	5.28	19.2	4.26	230	30	78	1.1	0.08	0.33	50	0	6	0.028	3.17	1.35	69
Parkwood	15	Surface Soil	Min.	4.55	42.7	2.95	440	21	58	1.1	0.16	0.12	26	1	0	0.046	1.52	1.94	15
			Max.	5.94	86.0	9.35	1860	236	171	5.1	1.4	0.24	465	20	20	0.124	3.29	2.84	24
	4	Subsoil	Aver.	5.31	62.5	5.04	1025	107	110	2.6	0.50	0.16	125	17	7	0.066	2.08	2.34	19
			Min.	4.36	54.5	0.80	148	13	19	0.5	0.16	0.06	10	3	0	0.011	0.53	1.45	25
Bladen	13	Subsoil	Max.	5.51	82.5	11.0	2650	495	332	1.7	0.96	0.12	2980	47	2	0.033	1.41	7.80	30
			Aver.	5.06	65.0	3.38	781	136	104	0.9	0.52	0.09	582	16	1	0.017	0.76	3.11	27
	1	Surface Soil	Min.	4.88	52.7	3.62	635	16	69	0.3	0.08	0.08	13	0	5	0.016	1.51	1.70	10
			Max.	8.31	100.	19.3	7000	465	416	9.3	2.2	1.2	745	34	375	0.517	10.6	4.00	19
1	Subsoil	Aver.	6.52	85.4	8.63	2717	194	206	3.2	0.45	0.30	220	12	48	0.144	3.66	2.48	15	
		Min.	4.81	46.0	1.18	304	24	37	0.3	0.08	0.06	10	0	1	0.016	0.50	1.22	13	
1	Subsoil	Max.	8.35	100.	27.6	9700	750	228	11.5	0.96	0.20	592	24	154	0.219	5.42	5.70	41	
		Aver.	6.68	83.7	6.71	2053	213	123	2.4	0.31	0.12	90	7	16	0.059	2.14	3.37	25	
1	Surface Soil	Min.	5.45	69.5	5.31	1215	73	250	27.	0.56	0.14	1240	36	6	0.065	1.68	3.16	15	
		Aver.	5.86	86.5	21.6	5700	795	855	12.	0.16	0.06	3160	96	0	0.040	2.25	9.60	33	